American Foundryman

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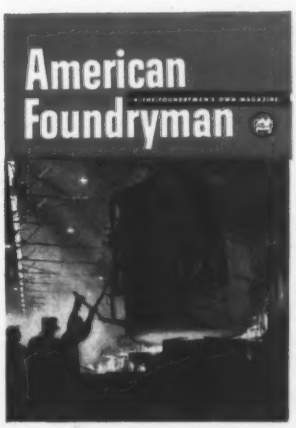

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Pouring operation in a modern production steel foundry—large, bottom pouring ladle holding entire electric furnace melt.

★ JULY WHO'S WHO ★

Harry Reitinger

In this issue Mr. Reitinger presents a discussion on *"50 Years of Progress in Foundry Time and Methods Study"* . . . Born in Philadelphia . . . Began his engineering career with Pure Water Apparatus Co., as consulting engineer . . . Later he became associated with Emerson Efficiency Engineers, New York . . . While affiliated with this firm he was assigned to the government as civilian engineer for installing distilling plants at various fortifications . . . During World World I was retained by the government for the manufacture of munitions . . . Returned to Emerson Engineers following the war . . . In 1922 began a long association with United States Pipe & Foundry Co. . . . Appointed resident manager of Burlington Works, Burlington, N. J. . . . In 1943 became connected with Bethlehem Steel Co., Bethlehem, Pa. . . . Rejoined the staff of Emerson Engineers a year later . . . Is a National Director of A.F.A. and a past chairman of the Philadelphia chapter.

C. E. Sims

Current article *"Cast Steels—Low Temperature Properties"* is jointly written by C. E. Sims and F. W. Boulger . . . Mr. Sims is a native of Chicago . . . Graduated from the University of Illinois, Urbana, with a Bachelor of Science degree in chemical engineering . . . Earned his Master of Science degree at the University of Utah, Salt Lake City . . . Entering industry, he served in various capacities with the Anaconda Copper Mining Co. in Montana; Michigan Electrochemical Co., Menominee, Mich.; R. W. Hunt Co., Chicago; Research Division, Chemical Warfare Service, Washington, D. C.; Aluminum Co. of America, Niagara Falls, N. Y.; U. S. Bureau of Mines Experimental Stations in Seattle, Wash., and Pittsburgh, Pa.; and American Steel Foundries, East Chicago, Ind. . . . Early in 1937 assumed his present position as supervising metallurgist, Battelle Memorial Institute, Columbus, Ohio . . . Has written widely for the technical press on subjects such as melting units, heat treatment, refractories and inclusions . . . Has presented numerous papers to A.F.A. meetings and has served on many Association committees, especially in connection with the improvement of steel castings procedures . . . In 1945 was presented the John A. Penton Gold Medal of A.F.A. . . . A member of A.F.A. he is active in the A.F.A. Central Ohio chapter.

E. J. Lally, Jr.

Mr. Lally is metallurgist with Forest City Foundries Co., Cleveland . . . Born in Cleveland, 1917 . . . Attended Case School of Applied Science, Cleveland, and was graduated with a Bachelor of Science degree in metallurgy June, 1939 . . . Following graduation he started his metallurgical career with Fanner Mfg. Co., Cleveland . . . In 1940 became associated with Taylor & Boggis Foundry Co., Cleveland, as metallurgist . . . Four years later (1944) assumed his present position . . . A member of A.F.A. and Gray Iron Research Institute . . . Paper written by Mr. Lally is entitled *"Cupola Refractories—Lining and Patching."*

F. W. Boulger

Co-author, with C. E. Sims, of *"Cast Steels—Low Temperature Properties"* . . . Born in Minneapolis, Minn., Mr. Boulger received his Bachelor of Science degree in metallurgical engineering from the University of Minnesota, Minneapolis (1934) . . . For one year (1934-35) was affiliated with Associated Press, Minneapolis, as traffic engineer . . . During 1935-36 was draftsman, Minnesota Department of Highways, St. Paul . . . From 1936-37 was research fellow, Ohio State University, Columbus, Ohio, and was awarded his Master of Science degree . . . Joined Republic Steel Corp., Cleveland (1937), as metallurgical observer . . . The following year, 1938, became a staff member of Battelle Memorial Institute, Columbus, Ohio, and is now assistant supervisor in metallurgy . . . Has written for the trade press and has prepared papers for technical societies . . . A member of AIME, ASM and A.F.A.

K. L. Clark

See in this issue: *"Fluidity Testing of Foundry Alloys"* . . . Author, K. L. Clark, was born in Phillips County, Kansas . . . Attended the Michigan State College of Agriculture and Applied Science, East Lansing, Mich., and was a member of the class of '33 . . . After receiving his Bachelor of Science degree he was made a graduate assistant at Michigan State . . . In 1935 he obtained his Masters degree and was appointed instructor at Michigan State . . . The following year (1936) became associated with Buick Motor Co., Flint, Mich., as metallurgist . . . Appointed assistant professor, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa, in 1939 . . . Became affiliated with the Naval Research Laboratory, Anacostia Station, Washington, D. C., as metallurgist in 1942 . . . Has contributed a number of papers to the technical press and has presented papers before meetings of various technical societies . . . Subjects dealt with include heat treatment of steel, carbon control and pyrometric practice . . . Membership affiliations include AIME, ASM and A.F.A.

R. A. Quadt

Research metallurgist, American Smelting & Refining Co., Barber, N. J. . . . Mr. Quadt, who was born in Woodside, N. J., is author of *"Aluminum Alloy"* . . . A 1939 graduate of Rutgers University, New Brunswick, N. J. . . . Has written for both the trade press and technical societies; papers have dealt with aluminum . . . Holds membership in AIME, ASM and A.F.A.

A.F.A. STEEL DIVISION STANDS READY TO SERVE INDUSTRY AND INDIVIDUAL

WORLD-WIDE WARFARE always results in rapid technological advancements. The past war, with its problems of new and increased demands for both old and previously unknown products, cut across the existing lines of progress to set up new standards for industry as well as temporary new standards of living.

For this reason, it is inevitable that the post-war period will be marked by outstanding social and industrial changes and improvements stemming from the proper utilization of wartime technology. Thus, foundries must be prepared to set aside pre-war standards and to assimilate quickly new standards of progress.

To aid this transition, foundries should look toward their technical society, the American Foundrymen's Association, to guide them in the proper utilization of technological advances, both present and future.

The steel foundry industry, through the Steel Division of A.F.A., is particularly favored with the opportunity to keep abreast of progress and "know-how" on foundry practice and metallurgy, for anything contributing to the literature and knowledge of the industry is of vital interest to the division.

The essential function of the division is to bring the important advances in steel castings technology before everyone having a direct interest in this phase of the foundry industry. This would include the producers and users of steel castings, the suppliers to the industry, the technical groups represented by the Government and other laboratories whose interests include steel castings, and those members of the staffs and student bodies of engineering schools whose interest lies in both the production and the use of cast steel.

The steel foundry industry can and should use the Steel Division of A.F.A. as its clearing house for the many new developments made and still to come. Progress comes only through cooperation, stimulated by a singleness of purpose, and the Steel Division has been noted in the past for the integrity and cooperative spirit of its members and committeemen.

The necessity for exchange of information—for technical papers, group discussions and other means of conveying to the membership results of current technological developments—seems more vital now than ever before in our history. A greater volume of information is available today, and the rate at which technological advancements are being made is increasing. The Steel Division looks forward, in this post-war era, to the important responsibilities in serving the industry and the individual, thereby benefitting our nation and mankind.

C. H. Lorig

C. H. Lorig, *Chairman*,
A.F.A. Steel Division.

C. H. LORIG, supervisor, Battelle Memorial Institute, Columbus, Ohio, began his industrial career in the Middlewest. Graduating from the University of Wisconsin, Madison, in 1924, he became affiliated with Stowell Co., Milwaukee. Thereafter he served with French Battery Co., Ladish Drop Forge and Drexel Institute. Well known as an author and speaker, Mr. Lorig writes and speaks on process metallurgy in relation to steel, cast iron and non-ferrous metals. Active in A.F.A. committee activities and a member of the Central Ohio chapter.

FOUNDRY PRACTICE FOR ENGINEERING STUDENTS

RECENTLY A.F.A. participated in the 54th Annual Meeting of the American Society for Engineering Education (formerly Society for Promotion of Engineering Education) when H. F. Scobie, educational assistant, American Foundrymen's Association, presented a paper at the Manufacturing Processes Session in St. Louis, June 23.

Entitled, "Foundry Practice for Engineering Students," the paper set standards for foundry courses and foundry instructors in engineering colleges.

Text of the discussion follows:

Engineering colleges and industry have a producer-consumer relationship which sometimes seems to have been overlooked in the preparation or revision of curricula. Now, when colleges are revising their curricula and developing a post-war model of engineering education, is the time for industrial needs to be considered.

As producers of graduate engineers, colleges should have the benefit of recommendations and suggestions from industrial plants regarding course material and objectives. In the role of consumer, that is, employer, of college graduates, industrial management can and will offer constructive criticism to the schools.

Cooperation between schools and industry results in more able engineering graduates and more satisfied employers. Educational institutions which consider industrial requirements when revising curricula may expect further assistance from industry, and will have the satisfaction of knowing they are fulfilling their educational function to the maximum.

Cooperation between schools and industrial groups is definitely and mutually profitable. This was shown recently when the foundry in a proposed college engineering building was redesigned and enlarged in accordance with A.F.A. suggestions.

The improved foundry will have superior equipment, will enable modern foundry practice to be taught, will make more efficient use of space, and be a great credit to the university. According to a department head, the foundry portion of the building project received special consideration because the foundrymen were the only representatives of any industry to offer assistance in planning the layout and equipment.

Two-Fold Function

Engineering colleges have a two-fold function to perform for the foundry industry and for engineering students. All engineering students should be trained in the basic principles and applications of cast metals. In addition, those interested should be given the opportunity to train for positions in the foundry industry.

Everything used and produced requires metal castings, directly or indirectly. Manufacturers, spending annually more than 3 billion dollars for castings of all sizes, shapes and of some 600 alloys, cannot afford to employ engineers who are unfamiliar with the economics of casting use, and casting design. Familiarity will be gained through a good basic course in the fundamentals of modern foundry practice, and through proper attention to cast metals in other engineering courses. Modern foundry practice demands close cooperation between designers, patternmakers and foundrymen.

Students desiring to learn more about the foundry industry should be able to take well planned and interesting advanced courses in foundry practice, thus enabling them to prepare for a career being selected by an increasing number of young men. The foundry industry needs young men with this training.

The need for improved basic courses is demonstrated every day in correspondence and telephone calls received at A.F.A. National Office.

A recent inquiry from an electrical engineer illustrates how uninformed on up-to-date foundry products a practicing engineer can be, and what a meager education he must have had in foundry practice. He requested a source of small electrical parts which, he insisted, had to be made of metal powder. Discussion brought out that the combination of properties required could be provided economically by a ferritic cast iron. The objection to a casting was that all castings contain, as he put it, "gas bubbles"!

Of course, all castings are not defective. If they were, aircraft designers, who of necessity must use low safety factors, would not specify castings of all types for aircraft construction. That foundries can and do produce castings of guaranteed quality was re-emphasized during the recent war.

Some educators are no more familiar with castings and casting uses than are many engineers. A not unusual example is the instructor of a course in internal combustion en-

gines who argued with his better-informed student that automotive piston rings are not made of cast iron. Actually only a negligible quantity of any type of piston ring is made of any other material.

The instructor in question probably would be surprised to learn that the average automobile requires about 500 pounds of cast iron. Automotive iron castings include the block, head, pistons, camshaft, crankshaft and brakedrums. Other automotive parts are produced from steel castings, malleable iron castings and the non-ferrous alloys.

Development of a good basic course in foundry practice requires, first of all, an appreciation on the part of engineering college administrators of the place of castings in our everyday life. Coupled with this must be the intent to have foundry practice taught as an engineering college subject rather than as a manual training course. Most department heads and many foundry instructors were educated at a time when a course in foundry practice consisted primarily of "pounding sand." Due to pressure of work, few have had sufficient time to study foundry developments of the past 20 years. As a result, engineering students suffer through an archaic foundry course not designed for modern needs.

Illustrations of the significance of castings to all of us, and to the economic life and development of America, are abundant. The recent war provides one example: ordnance armor programs would have bogged down had it not been for the enormous quantities of cast armor provided by skilled foundrymen. Present sluggish return of the country to peacetime production is due, in part, to inability of foundries to provide castings as rapidly as other industries need them. A basic industry, the foundry must return to normal before any other industry can reach full employment and production. These facts should be kept in mind by department heads expecting to stimulate improvement of foundries under their administration.

Colleges recognizing the importance of castings set high standards for foundry instructors. Such colleges use the same care in selecting a foundry instructor that is used in selecting any other faculty member. Sufficient time and thought are devoted to the problem of the selection that the foundry instructor is not employed at the last minute. Late selection too often results in employing a man willing to take the position only because he can find no other. Such an instructor is not a credit to the school, nor can he satisfactorily serve the student body or the foundry industry.

An engineering college foundry instructor should have a good educational and industrial background, as well as proven interest in castings and the foundry industry. To teach modern foundry practice, he should be a graduate in metallurgy, or in chemical or mechanical engineering, with electives in metallurgy. He should have had experience in several types of foundries, not only in a gray iron shop. Experience in steel and malleable foundries and in shops casting light-metal alloys, and others, is highly desirable.

The college foundry instructor should be interested in improving himself and his courses; if he does not hold an advanced degree, he should be required to work toward it.

The ultimate in foundry instructors is a professionally capable man who stimulates his students and has their respect, a man able to select and influence promising students.

More Men Available

An increasing number of young men with the qualifications for, and the interest in, teaching modern foundry practice are becoming available. Some of these men have been employed by engineering colleges. Instructors with other qualifications but lacking commercial foundry experience can be aided by summer employment in foundries. This helps the foundry instructor balance his budget and gives him the industrial contact that most university staff members need.

Even the most enthusiastic foundry instructor welcomes a change, and so do the students. The Wisconsin chapter of the American Foundrymen's Association has worked out a plan with the University of Wisconsin whereby 15 one-hour lectures on foundry practice are delivered by foundrymen who are specialists in their field. The students receive first-hand information about the commercial production of castings, and have an opportunity to see the type of men engaged in the technical fields of the foundry industry. A similar program is in prospect at Marquette University, Milwaukee.

The Wisconsin plan has proven profitable to the university. It has also demonstrated to engineering students that the foundry industry offers a place in which to apply engineering techniques, and in which the opportunity to advance is great. The latter is due to a shortage of technically trained men in the industry, at a time when the number of complex technical problems is inordinately large.

Once the engineering college administration and the foundry instructor have agreed that a modern course in foundry practice is to be offered, the question arises: what is a modern foundry course?

Modern foundry courses have been taught by some schools for a number of years. Schools teaching foundry practice according to current needs of the industry are recognized and encouraged by the foundry industry.

Schools with up-to-date foundry curricula were commended by N. F. Hindle* of the A.F.A. National Office, in a paper presented at the 50th Anniversary Meeting of S. P. E. E. held in Chicago in 1943. He indicated the necessity of teaching foundry practice as an engineering course, not as a manual training course. Stating that "the courses should cover processes and products," he added that they "should deal with the metals cast and their application, the properties available and some metallurgy."

Mr. Hindle's paper presented the current point of view regarding a general course in foundry practice. Emphasis is on castings design, cooperation between designer, patternmaker and foundryman, casting properties, and the economics of casting use. This is reasonable since all engineers use castings, whereas, only a small, though increasing, number are concerned directly with castings production.

Molding, coremaking, melting and other foundry techniques are necessary in a general foundry course only to the extent that they enable the embryo engineer to better understand the use and design of castings.

The older system of laboratory periods only, without formal lectures, has been discarded by some engineering colleges. Foundry instructors in progressive engineering colleges

*N. F. Hindle, "Casting Design and Engineering Curricula," *J. Eng. Educ.*, vol. 34, no 7 (March 1944).

devote about half the available class hours to lecturing. Emphasis is not placed on handing down a collection of traditional knowledge, but rather on the ideas behind the tradition. Instead of 'know-how,' interest centers on 'know-why.'

Typical of the modern trend in foundry instruction is the series of courses reported by Holtby and Scobie** in "A University Course in Foundry Control Methods." Described are an elementary foundry course required of mechanical engineering and metallurgical students, and a series of elective courses for advanced students. Primary purpose of the elementary course, taught to approximately 225 students each year (1941), is to acquaint engineering students with modern foundry practice, the possibilities and limitations of castings for engineering use, and important factors in design.

This elementary course, offered at the University of Minnesota, stressed four points:

1. The development of the foundry industry during the past two decades, and the improvement in its products.
2. The importance of control in foundry processes.
3. The practical knowledge applicable in other fields.
4. The increasing opportunities for employment as an engineer.

The discussison of the paper, which appears in the 1941 TRANSACTIONS of A.F.A., is encouraging because it illustrates a favorable trend in foundry education among some schools.

Instruction in foundry practice should be coordinated with the pattern shop, courses in other manufacturing processes, and with machine design, materials testing, materials and processes.

Patternmaking should be very closely integrated with the course in foundry practice. If the courses are not taught by the same instructor, or are not under the jurisdiction of one man, there should be agreement on their content to eliminate unnecessary overlapping. Important, also, is agreement on foundry and pattern terminology, pattern colors, allowances for draft, shrinkage and machining, etc.

An engineering college course in pattern practice should not stress the use of woodworking tools or attempt to make a patternmaker of the student. Elementary woodworking, that should have been learned in high school or at a home work bench, has little place in a crowded engineering curriculum. The college pattern course ought to include pattern construction for maximum moldability and economy of production, types of pattern equipment, pattern construction materials, and perhaps permanent mold construction.

Courses in which mechanical and physical properties of cast metals are discussed should be in agreement on these properties. If heat treatment of castings is taught in courses other than the one in foundry practice, the purposes, principles and results of heat treatment should be the same in all courses. If machinability of cast metals is considered in the foundry course, machinability ratings and methods of testing should be consistent with those taught in the machine shop.

Design Principles

Principles of casting design must be the same in the foundry and machine design courses. Metallurgy of cast metals taught by the foundry instructor should agree with the teachings of the instructor in metallurgy. The industrial engineering department and the foundry department should have the same thoughts on economics of casting use, plant layout, and mechanical equipment. The high temperature chemistry of metals, refractories, fuels and fluxes should be taught in essentially the same way whether the lecturer is a foundry instructor or a teacher of chemistry.

Schools interested in developing or improving courses in foundry practice are offered the assistance of the American Foundrymen's Association. Seven national committees established for that purpose are composed of prominent foundrymen as well as educators in the field of metallurgy, engineering and foundry practice.

These committees have actively cooperated with engineering schools, making recommendations regarding course content, text books, laboratory layout and equipment, correlation with other courses, research projects; and have annually sponsored an essay contest, discontinued during the war, for engineering college students.

Several engineering colleges have recently revised and expanded their curricula as a result of contact with foundry industry representatives.

Case School of Applied Science, in cooperation with the Northeastern Ohio chapter of A.F.A., has worked out a course expected to provide effective training for students who plan to enter the foundry business.

Massachusetts Institute of Technology has just announced the organization of a Metal Processing Laboratory under the direction of a full professor. The latter will have the assistance of a joint committee from the Metallurgy and Mechanical Engineering Departments.

Heading the foundry laboratory will be an associate professor. The program is expected to be flexible enough to suit the needs of any part of the foundry industry. Students may specialize in the mechanical, the metallurgical, or the managerial aspects of foundry work. Degrees offered will be B.S., M.S., and D.Sc.

These examples, and others which could be cited, illustrate the trend in foundry education. Schools anticipating foundry industry needs and sympathetic with its requests often find that scholarships are established, summer employment is provided for foundry instructors and foundry students, teaching aids and casting exhibits are supplied, books are donated to engineering libraries, and equipment given for teaching and research.

Recognizing the importance of an industry producing over 20 million tons of castings annually, some engineering colleges are overhauling their foundry courses to meet present day requirements. Responding to industrial needs, department heads are reviewing foundry courses under their administration and studying ways of cooperating with casting producers. Foundry instructors are aiding by reorganizing course material to meet the need for engineering graduates with knowledge of casting properties, applications and design.

Educational committees and the 33 chapters of the American Foundrymen's Association will continue to encourage and advise engineering colleges in the development of improved foundry instruction.

College graduates, adequately trained and cognizant of opportunity, are entering the industry because they recognize that the foundry is a good place in which to work.

**F. Holtby and H. F. Scobie, "A University Course in Foundry Control Methods," TRANS., A.F.A., vol. 49, p. 310 (1941).

ALUMINUM ALLOY

An investigation of the effect of certain elements on the mechanical properties of an aluminum sand casting alloy with a composition of 1 per cent copper, 5 per cent silicon, and 0.5 per cent magnesium.

R. A. Quadt
American Smelting & Refining Co.
Barber, N. J.

THIS INVESTIGATION was conducted on a group of aluminum sand casting alloys with a nominal composition of 1.0-1.5 per cent copper, 4.5-5.5 per cent silicon, and 0.4-0.6 per cent magnesium. It is described as A.F.A. Alloy B-41[1]. Specifications by other agencies include QQ-A-601, class 10; SAE 322; ASTM B26-44T (Alloy SC 21); AN-QQ-A-376 Am.2; and AMS 4210.

For convenience, this alloy will be referred to in this paper as F150.5 in accordance with a system of nomenclature in which aluminum castings are defined according to their copper, silicon, and magnesium content to the nearest integer in the indicated sequence.

Magnesium

Because of the effectiveness of small amounts of magnesium in these alloys, this element is indicated in tenths of a per cent. The actual alloys used are representative commercial composition within the F150.5 specifications. The mechanical properties specified for this alloy are listed in Table 1.

As will be subsequently proven, the solution treated alloy is unstable and begins to age at room temperature immediately after quenching. After a few weeks the properties of the quenched alloy approach those of the alloy aged 3-5 hr. at 310° F. (Table 1).

This hardening process is accompanied by dimensional changes and, for this reason, the as-quenched alloy is seldom used commercially and an artificial aging treatment similar to that of the 3-5 hr. at 310° F. (Table 1) is utilized to obtain properties which are essentially stable upon subsequent room-temperature aging. This is the most commonly used heat treated temper for this alloy.

Heat treatments similar to the solution treated, quenched, and aged 12 hr. at 310° F. (Table 1) are occasionally used when high strength properties are required for specific applications. No specifications exist for the alloy in the as-cast condition although excellent properties are obtained. The as-cast alloy may be stabilized and stress relieved by heating to a temperature of 450° F. for 5 hr. and air cooling.

Various similar stress relief treatments are used commercially, but the work described in this paper was limited to this one treatment when stabilized properties were studied.

F150.5 is a comparatively new aluminum alloy which has been used in large tonnages in the past few years, particularly in air craft castings. This widespread acceptance of the alloy in aluminum foundries stems from its desirable combination of chemical and physical properties.

It has excellent foundry characteristics in that it is extremely fluid at low casting temperatures, produces pressure tight castings, casts readily into thin sections, has low solidification shrinkage, as compared to other aluminum casting alloys, and is essentially free from hot shortness.

Corrosion Resistant

It machines well, especially after heat treatment, and has high resistance to corrosion in saline atmospheres. It is an excellent general purpose alloy in that a foundry may use it for all types of castings since a wide range of mechanical properties can be obtained by using the alloy in the as-cast condition or in various heat treated tempers.

Melting and Casting Procedure. All melts were made in No. 45 clay-graphite crucibles in a coke-fired,

Table 1

ALUMINUM ALLOY MECHANICAL PROPERTIES

	Properties		
Heat Treatment	*Tensile Strength (min.), psi.*	*Avg. Yield Strength* (0.2% offset), psi.*	*Elongation (min.), per cent in 2 in.*
Solution Treated and Quenched	27,000	20,000	4.0
Solution Treated, Quenched, and Aged 3-5 hr. at 310° F	32,000	25,000	2.0
Solution Treated, Quenched, and Aged 12 hr. at 310° F	36,000	33,000	0.5

*Yield strengths almost invariably are listed as "average" or "typical" in specifications of this and other aluminum casting alloys.

Presented at an Aluminum and Magnesium Session of the Fiftieth Annual Meeting, American Foundrymen's Association, at Cleveland, May 7, 1946.

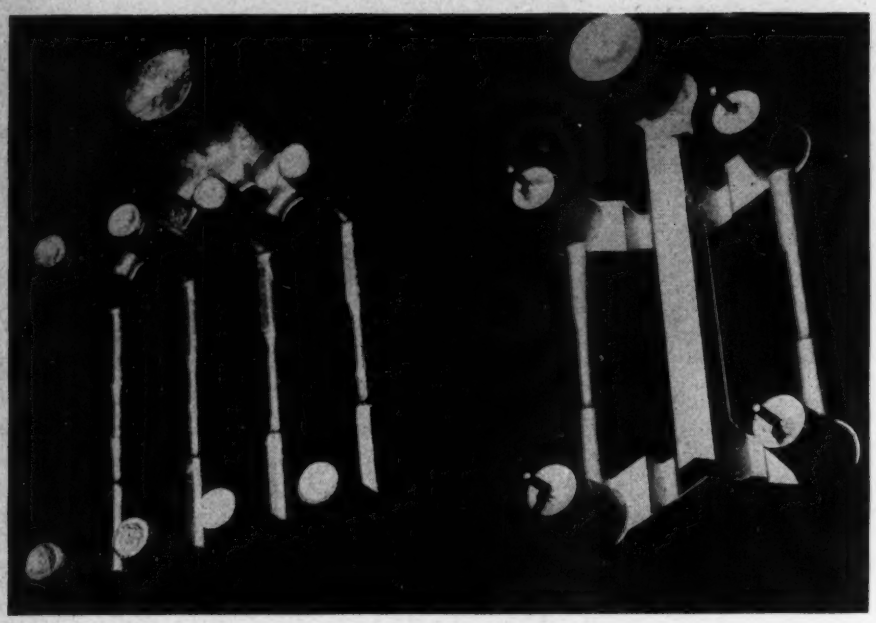

Fig. 1—Types of castings utilized to obtain cast to size tensile specimens. About 1/7 actual size.

forced draft, pit furnace. About 30-45 min. was required to melt 50 lb. of metal. Ingots or pieces of test bar castings were continually added to the melt through the top cover of the furnace during melt down. This guaranteed that no moisture was present on the metal by the time it was submerged in the previously melted alloy.

Surface hydrates were assumed to be negligible due to short intervals of storage and to favorable storage environment. When all of the metal was in the crucible and the hardener or alloying element, if any, completely dissolved, the metal was stirred with a one in. diameter graphite rod. The crucible was then removed from the furnace. Typical metal temperatures at this time ranged from 1400 to 1600° F. A few ounces of sodium silico fluoride was gently worked into the top dross to assist in its removal.

Metal Cooled

The metal was then permitted to cool quietly to the desired pouring temperature, nominally 1220° F. unless otherwise specified. No degassing operation was performed and no grain refiners were added to any of the heats reported. Temperatures were determined with a protected chromel-alumel thermocouple in conjunction with a portable Leeds and Northrup potentiometer.

The metal was cast into green sand molds to produce standard ½-in. diameter cast-to-size tensile specimens. Two types of castings were used and are shown in Fig. 1. No difference in mechanical properties could be detected in the specimens from either type of casting. About 75 per cent of the bars cast were obtained from the 4-bar casting since twice as many bars per lb. of aluminum are produced and fewer instances of inclusions experienced.

Specimens Poured

Cast-to-size impact specimens were also poured from most of the heats. The casting is shown in Fig. 2 and produces twenty-six 10x10 mm. Charpy specimens. Half of the specimens are unnotched and the rest have a standard V-notch cast into the drag. The specimens were tested unmachined on a modified Charpy impact machine of 16 ft.-lb. capacity. The production of impact specimens by this method has been discussed elsewhere[2].

Heat Treatment Practice. Solution heat treatments were conducted in an electrically heated, circulating air furnace. Bars were nominally soaked 12 to 15 hr. at 980° F. ± 5° F. and quenched in boiling water.

To standardize the procedure, bars were aged for one day at room temperature before being tested for solution heat treated properties or before being artificially aged at elevated temperatures. The stress relief treatment given as-cast specimens consisted of heating for 5 hr. at 450° F. and air cooling.

All low temperature treatments were carried out in electrically heated, constant temperature fused salt baths. The temperature was automatically controlled to within ± 2° on each of three baths set for 310° F., 400° F., and 450° F.

Properties listed for the as-cast temper were obtained from one to 4 days after casting unless otherwise noted.

Alloying Procedure. Since magnesium, nickel, and zinc readily dissolve in aluminum they were added as pure metals. Iron and manganese were added as hardeners, which were made by melting a few lb. of the alloy under investigation and adding the desired quantity of these elements. By this procedure dilution of the initial composition was minimized.

Chemical determinations were made on the final test bars, not on the intermediate hardener. Whenever an alloy was remelted, 0.03 per cent magnesium was added to make up for the amount lost in the process. Occasional chemical determinations were made to check the magnesium content of the final alloy since this element has a critical effect on the properties obtained.

Effect of Pouring Temperature and Overheating. An alloy of the

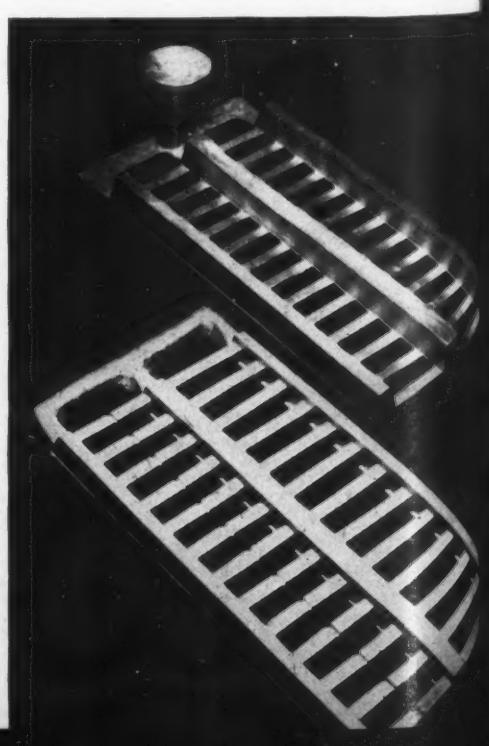

Fig. 2—Casting for producing cast to size 10x10—mm. Charpy impact specimens. Top—Cope view. Bottom—Drag view.

composition shown in Table 2 was used to determine the effect of casting temperature on some properties in the as-cast or "green" temper.

The alloy was melted and heated to a temperature of about 1700° F. After removal from the furnace and skimming, a series of castings was poured at various temperatures. The melt was permitted to cool quietly in the crucible between pours.

That the pouring temperature is of considerable significance on the properties of a casting is clearly shown in Fig. 3. It is also indicated that overheating the alloy does not affect the final properties if the metal is permitted to cool to the proper casting temperature.

This absence of any effect on the final properties due to previously overheating the metal has been checked on most other common aluminum casting alloys with the same result.

Some data to this effect have been reported elsewhere[3]. This does not concur with the widely promulgated assertion that overheating (in excess of 1500° F.) aluminum casting alloys favors coarsening of the final grain with a resultant deleterious effect on properties[4,5,6]. This result has never been experienced by the author.

Grain Size

In the absence of an active grain refiner, many tests on various aluminum alloys have indicated that grain size and mechanical properties of test bars are largely determined by the final casting temperature and are little if at all related to the thermal history of the melt. This may not be true of high-purity alloys since all tests were conducted on commercial alloys with analyses in the commercial range.

For such commercial alloys the grain size of tensile bars can be controlled by pouring temperature alone and superheating is not a factor. Should titanium be present and still retain grain refining properties, overheating, or even holding at moderate temperatures, should be avoided since these procedures reduce the effect of the titanium and a coarser grained casting will result.

However, it is important to note that this grain coarsening is due to the effect of temperature upon the titanium constituent and not upon the aluminum.

Hydrogen Free

It is of utmost importance to recognize, however, that these experiments were conducted in furnace atmospheres which were essentially free of hydrogen compounds, hence typically sound castings resulted.

In a furnace atmosphere containing combustion products from gas, oil, or coal, overheating should be kept to a minimum since the solubility of the hydrogen obtained from the compounds present increases with the temperature of molten aluminum, and excessive porosity may result which will cause inferior properties. These experiments do prove that overheating, other factors being equal, is not deleterious.

Another test which indicates the desirability for low pouring temperatures was performed on the alloy composition shown in Table 3.

It was melted in the described manner, cast at 1220° F. and the specimens heat treated and tested. Upon completion of these tests the alloy was remelted and recast at 1300° F. Similar mechanical tests were conducted on the alloy. The results of these tests are plotted in Fig. 4. Ultimate strength has been markedly reduced, ductility has been slightly impaired, while yield strength is unaffected. Thus a pouring temperature of about 100° F. above the optimum detracts from the quality of the casting.

At least a part of the reason for the inferior properties accruing from a high pouring temperature is the resulting increased grain size. Fig. 5 portrays the difference in crystal structure between tensile specimens cast at 1220° F. and at 1300° F.

It will be noted that Fig. 5 indicates a greater difference in grain size between the two pouring temperatures than would be predicted

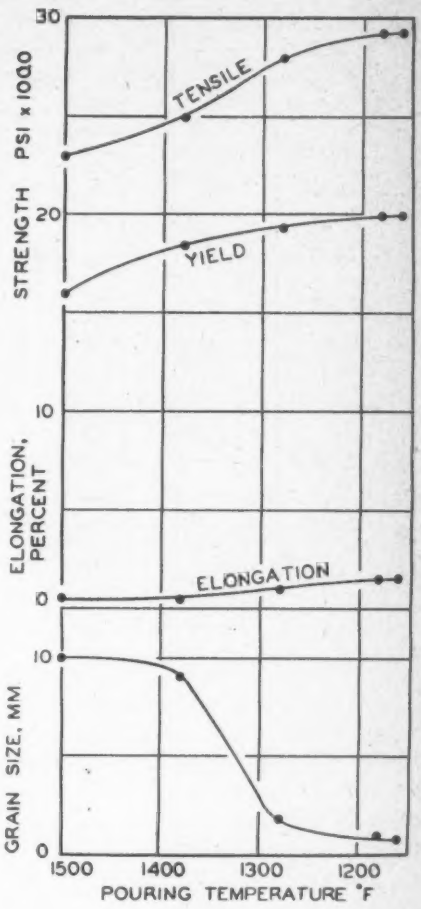

Fig. 3—Effect of pouring temperature on as-cast properties. Specimens poured from the same crucible.

from the curve given in Fig. 3. The latter data were obtained from two-bar castings while the former resulted from the four-bar type. The metal for the rear risers of the four-bar casting passes through the tensile section and heats the sand.

Retards Freezing Rate

This retards the freezing rate of the bars appreciably, and at elevated temperatures a coarser grain results. Utilization of this type of casting displaces the grain size curve shown

Table 2

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.68
Silicon	5.13
Magnesium	0.58
Manganese	0.42
Iron	0.74
Nickel	0.04
Zinc	0.33
Chromium	0.005
Titanium	0.005
Aluminum	Balance

Table 3

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.23
Silicon	5.21
Magnesium	0.46
Manganese	0.43
Iron	0.54
Nickel	0.02
Zinc	0.35
Chromium	0.10
Titanium	0.13
Aluminum	Balance

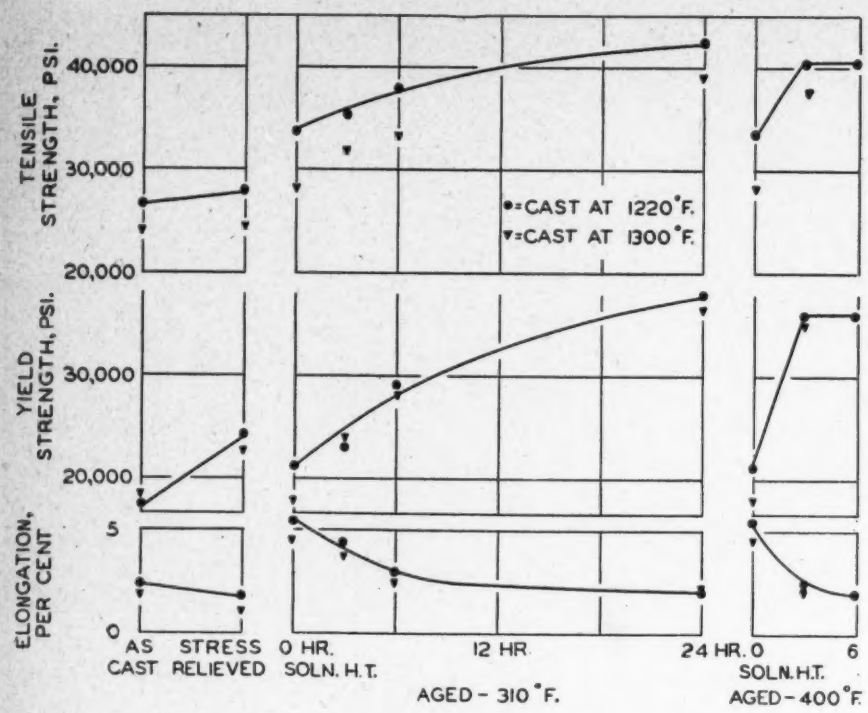

Fig. 4—Effect of pouring temperature on some mechanical properties.

in Fig. 3 to the right. Occasionally tensile bars from this casting will show a grain size gradient ranging from coarse at the sprue end to relatively fine at the rear risers.

In the two-bar casting, on the contrary, two streams of metal meet in the center of the reduced section and the freezing rate must be maximum at this point. A grain size gradient has never been observed in bars from this type of casting.

Effect of Magnesium. F150.5 alloy responds to heat treatment largely because of the magnesium and silicon in the composition. Of these two elements the magnesium content is most critical in determining the alloy's mechanical properties, whether heat treated or not. In a test to prove this fact, some properties of the alloy shown in Table 4 were determined.

Alloy Remelted

It was then remelted and the magnesium removed. The properties were redetermined on the resulting alloy, which then contained 0.002 per cent magnesium, and are compared in Fig. 6. It is seen that the initial alloy reacts to heat treatment while the same alloy without magnesium shows essentially no response to heat treatment.

Both sets of properties shown in Fig. 6 are lower than would normally be expected because the data were obtained for another purpose from test bars cast at 1350° F., an excessively high temperature for pouring test bars from this alloy. The data reflect the effect of the magnesium content, notwithstanding.

Aging Treatments

On another alloy of the composition shown in Table 5 the effect of magnesium was further investigated. After mechanical properties were obtained on this alloy it was remelted and magnesium added, which raised this element to 0.56 per cent. The effect of various aging treatments on solution treated specimens of the two alloys is plotted in Fig. 7.

Marked instability of the as-quenched alloy on standing at room temperature is indicated. A large amount of aging occurs the first day, followed by further aging at a reduced rate. The hardening process

Table 4

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.68
Silicon	5.13
Magnesium	0.53
Manganese	0.34
Iron	0.79
Nickel	0.00
Zinc	0.30
Chromium	0.005
Titanium	0.005
Aluminum	Balance

is largely completed in a few weeks. It is clear that the magnesium content is critical in this alloy.

Addition Made

Since the element is slowly lost on remelting and fluxing, an addition must be made to maintain correct composition. In general, increasing magnesium contents in this alloy produce higher tensile and yield strengths combined with reduced ductility for any particular temper.

Effect of Nickel. Chemical specifications variously require that nickel be limited to 0.05 or to 0.10 per cent in this alloy. Figs. 8, 9 and 10 show the effect of increasing nickel on the F150.5 alloy shown in Table 6. These data indicate that nickel as high as 0.3 per cent has essentially no effect on the alloy. More than this amount generally impairs most properties.

A summary of the effects of high nickel is as follows: The strength is reduced, tensile and yield strengths approach each other, and serious reductions in elongation and impact strength occur. As a concession to clarity the impact strengths in these and in some subsequent plots are averaged for the tempers being considered.

The nickel can be detected in the microstructure even when only 0.1 per cent is present. It is apparently almost insoluble in the solid alloy.

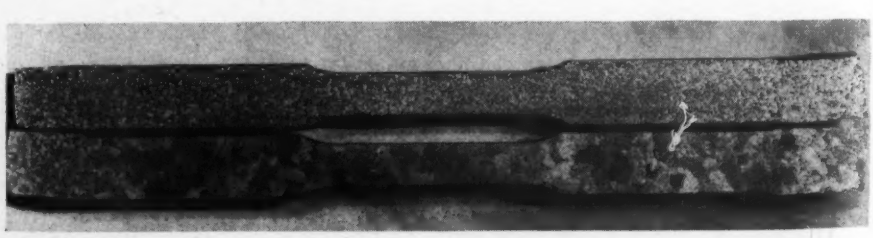

Fig. 5—Axial tensile bar sections, 2/3 size. Etchant, 1 per cent HF. Top—Grain structure of casting poured at 1220° F. Bottom—Grain structure of casting poured at 1300° F.

Table 5

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.58
Silicon	5.22
Magnesium	0.18
Manganese	0.50
Iron	0.67
Nickel	0.04
Zinc	0.28
Chromium	0.10
Titanium	0.01
Aluminum	Balance

It is found only in the eutectic structure, probably as the compound $NiAl_3$ (Fig. 11). Heat treatment has no effect upon its structure or appearance.

Effect of Zinc. Zinc in F150.5 alloy is limited to maximums ranging from 0.03 to 0.30 per cent, depending upon the chemical specification consulted. The curves in Figs. 12, 13, and 14 indicate the effect of increasing zinc on some properties of the initial alloy shown in Table 7.

It is obvious that no deleterious effect accrues from zinc additions until more than one per cent is present in the alloy. The microstructure reveals no change in the form or occurrence of the usual constituents as the zinc content is increased to 2.5 per cent. This is not surprising since relatively large amounts of zinc are

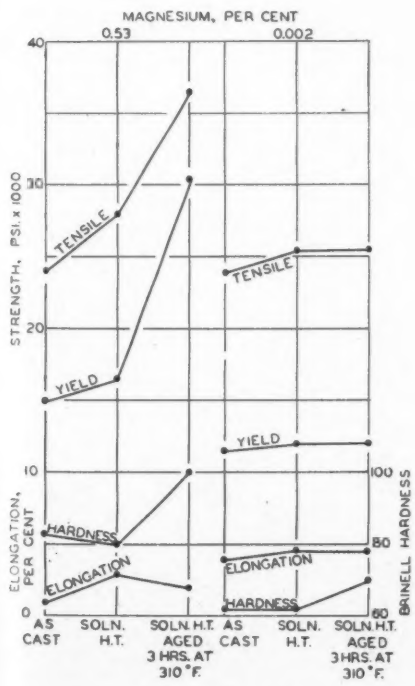

Fig. 6—Effect of magnesium on mechanical properties and heat treatability.

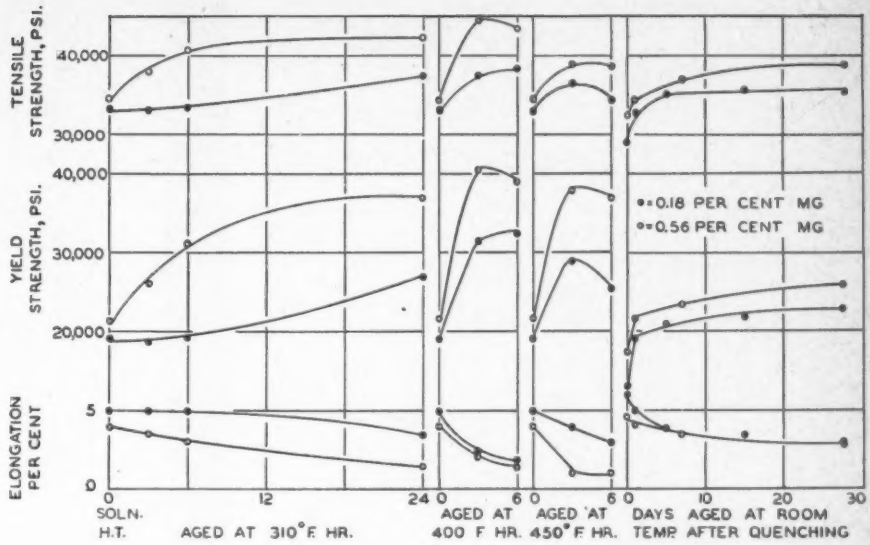

Fig. 7—Effect of magnesium on some heat treated mechanical properties.

soluble in the solid alloy at room temperature even under conditions of thermal equilibrium.

Effect on Manganese. This element is limited in amounts varying from 0.03 to 0.6 per cent in this alloy by the existing chemical specifications. Figures 15, 16, 17 and 18 summarize the resulting properties obtained upon adding manganese to the alloy of the composition shown in Table 8.

Up to one per cent of manganese generally improves the mechanical properties of F150.5 alloy in the tempers most commonly used. It does, however, accelerate the rate of overaging upon subjecting the solution treated alloy to temperatures of 400° F. or over, although this tendency is not pronounced with less than one per cent of manganese.

Microstructure Changed

Two changes were noted in the microstructure as a result of the manganese additions. The structure of the initial alloy included needles of beta (Fe-Si), utilizing the nomenclature of Phillips and Varley[9].

Addition of 0.3 per cent of manganese eliminated these needles or plates, and the secondary alpha (Fe-Si) phase was apparent in its usual "Chinese script" habit. The structural change and its effect will be more completely discussed later. The alloy containing 1.65 per cent of manganese revealed masses of alpha (Mn-Si) instead of the previous script, and is shown in Fig. 19.

Effect of Iron. It is generally required that iron be under 0.5 or 0.6 per cent in sand castings of F150.5 alloy. The effect of iron was investigated by adding it in various increments to the initial alloy shown in Table 9.

Results of these tests are plotted in Figs. 20, 21, 22 and 23. Generally, iron under one per cent has no effect on the properties measured. As iron is increased over this amount it has only slight influence on properties except upon aging at the relatively high temperature of 450° F. It decidely influences the rate of overaging at this temperature, increasing it to a marked degree.

Effect of Iron

However, iron as high as 2.4 per cent has only an insignificant effect on the properties measured in all the other tempers. Curiously enough, this high iron appears to retard the rate of aging to a slight degree upon precipitation hardening at 310° F.

At the same time, it has no effect whatever when solution treated and aged at 400° F. and, in fact, appears to slightly improve the strength of

Table 6

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.35
Silicon	5.52
Magnesium	0.55
Manganese	0.01
Iron	0.34
Nickel	0.01
Zinc	0.04
Chromium	0.10
Titanium	0.05
Aluminum	Balance

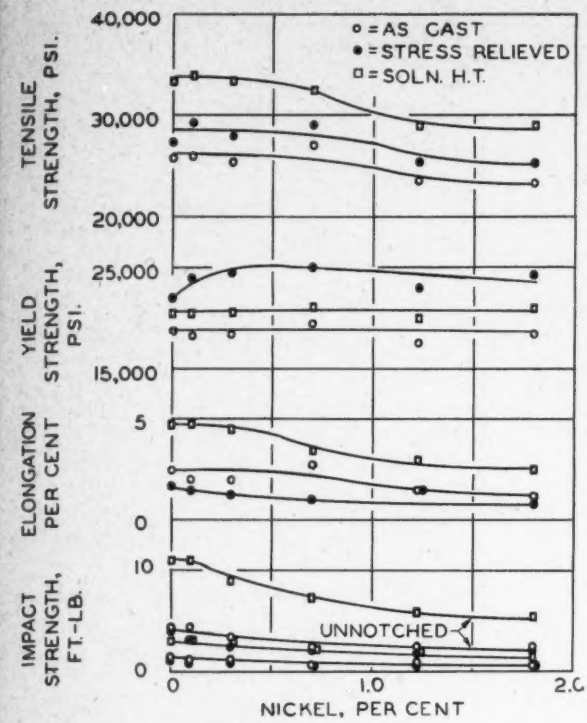

Fig. 8—Effect of nickel on some properties in the as-cast, stress relieved, and solution heat treated tempers.

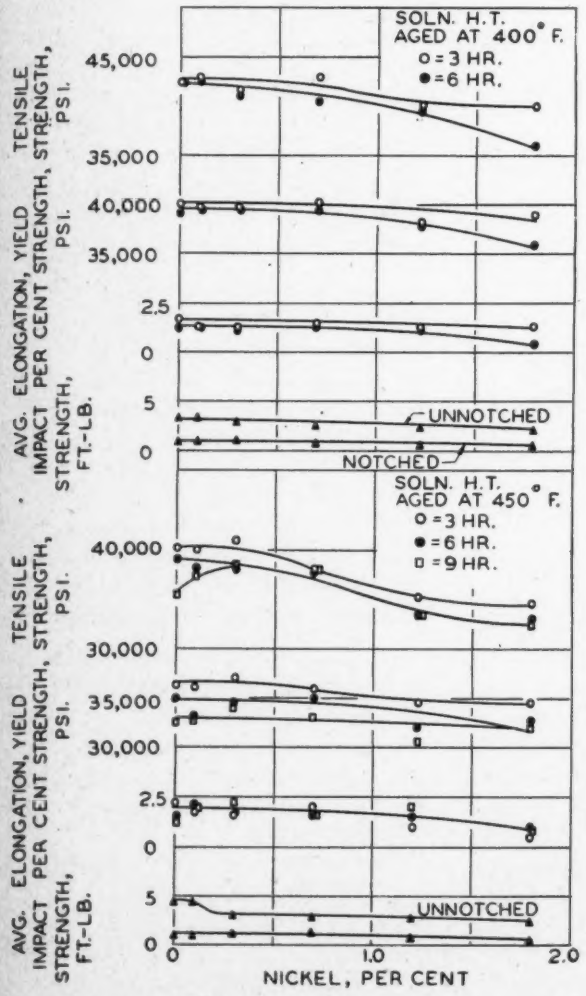

Fig. 10—Effect of nickel upon solution treating and aging at 400° F. and 450° F.

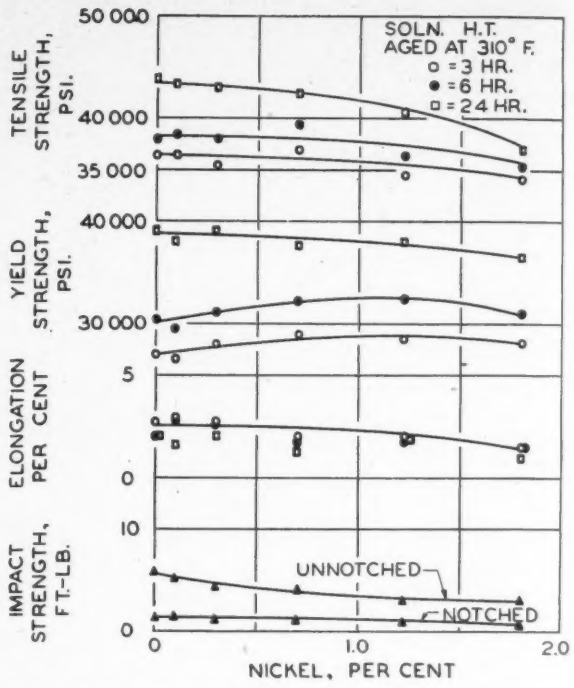

Fig. 9—Effect of nickel upon solution treating and aging at 310° F.

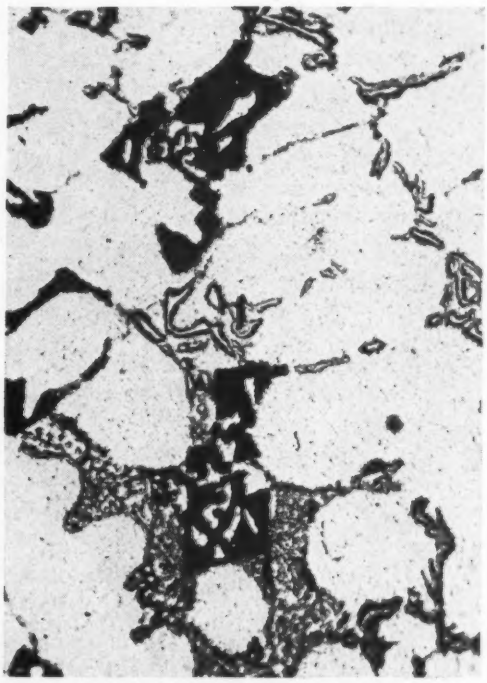

Fig. 11—As-cast structure of an F150.5 alloy with 1.8 per cent nickel. $NiAl_3$ (black), eutectic (mottled), silicon (bright), dendritic alpha (speckled). Etchant, 1 per cent HF. 300X.

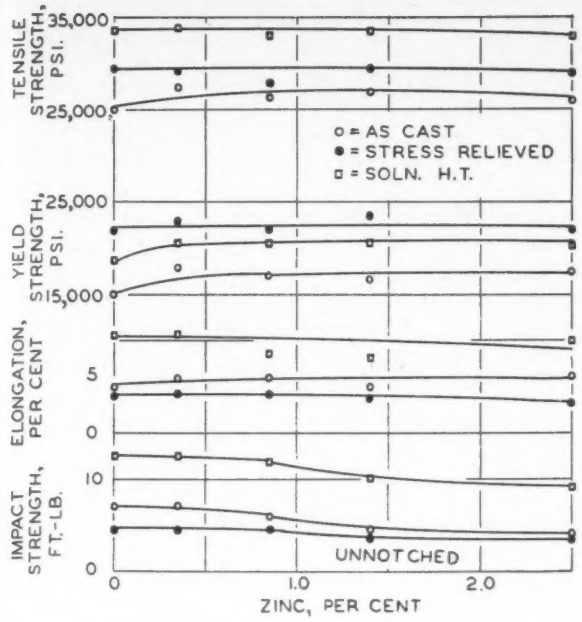

Fig. 12—Effect of zinc on as-cast, stress relieved, and solution heat treated properties.

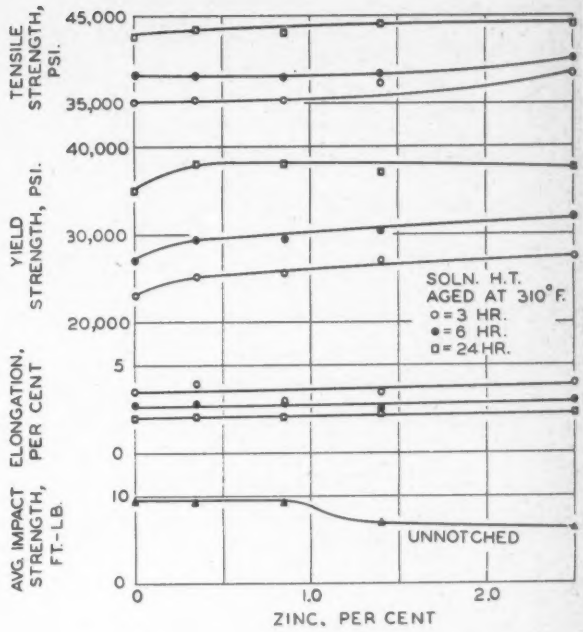

Fig. 13—Effect of zinc upon solution treating and aging at 310° F.

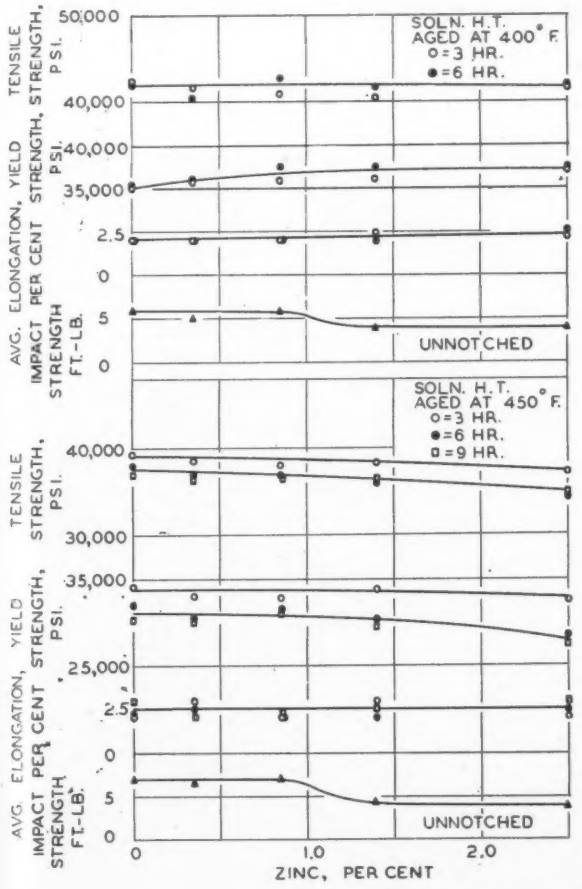

Fig. 14—Effect of zinc upon solution treating and aging at 400° F. and 450° F.

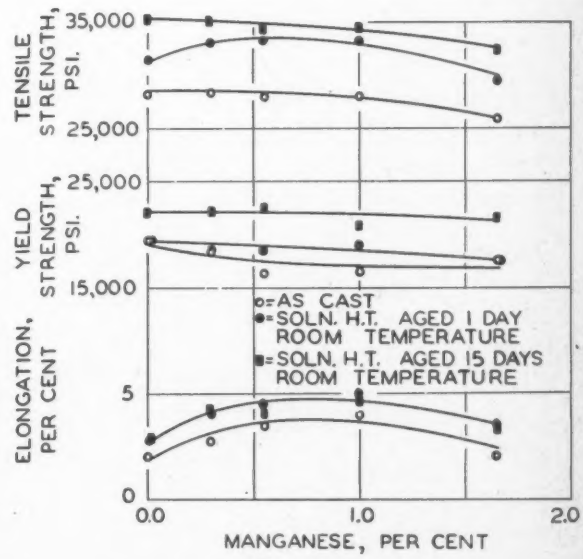

Fig. 15—Effect of manganese on as-cast and solution heat treated properties.

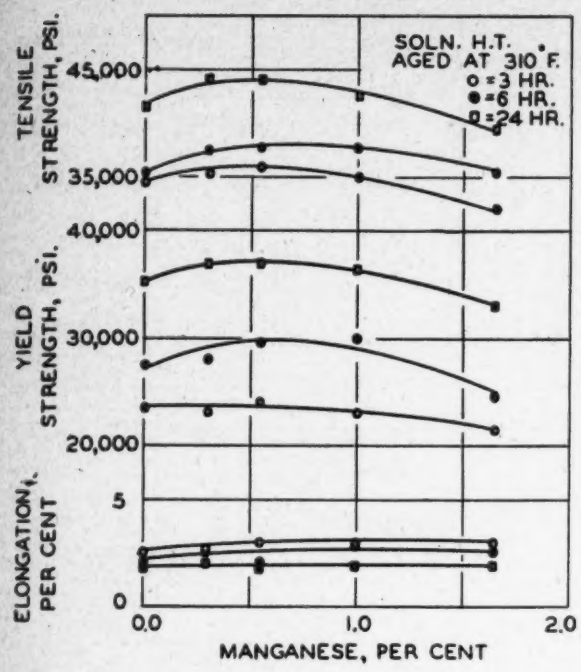

Fig. 16—Effect of manganese upon solution treating and aging at 310° F.

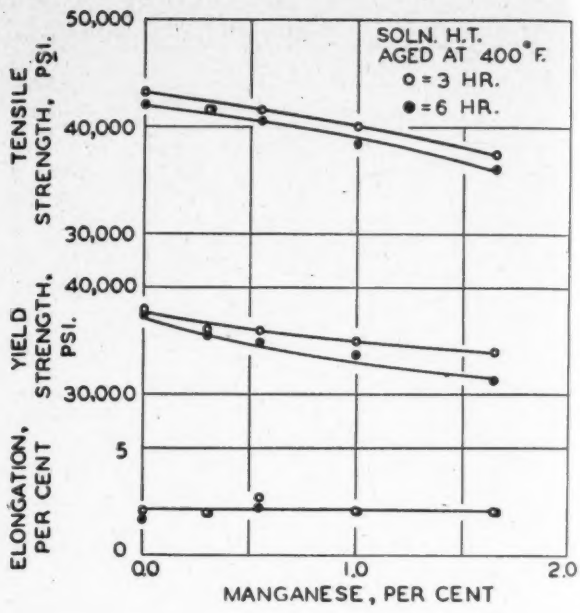

Fig. 17—Effect of manganese upon solution treating and aging at 400° F.

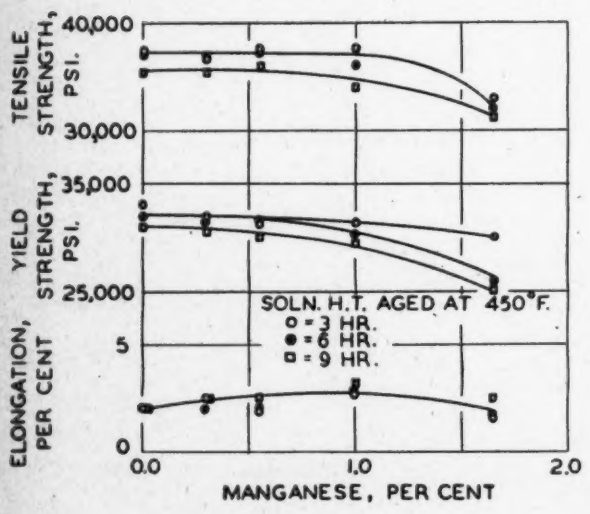

Fig. 18—Effect of manganese upon solution treating and aging at 450° F.

Fig. 19—As-quenched alloy with 1.65 per cent manganese. Alpha Mn-Si (in relief), silicon (half tone). Etchant, 1 per cent HF. 300X.

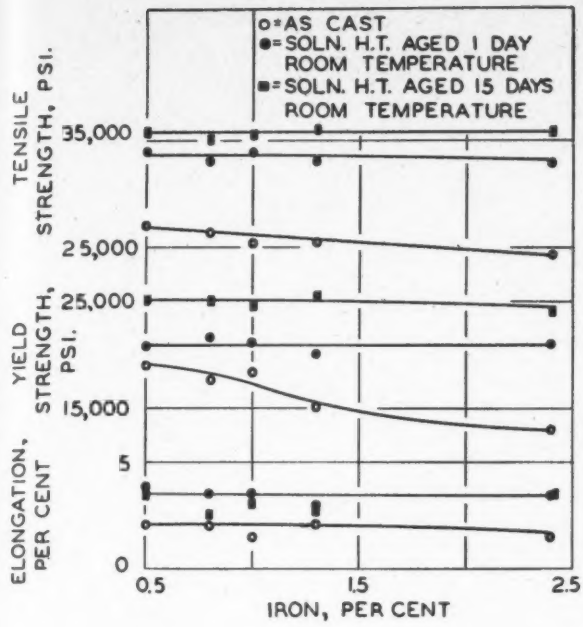

Fig. 20—Effect of iron on as-cast and solution heat treated properties.

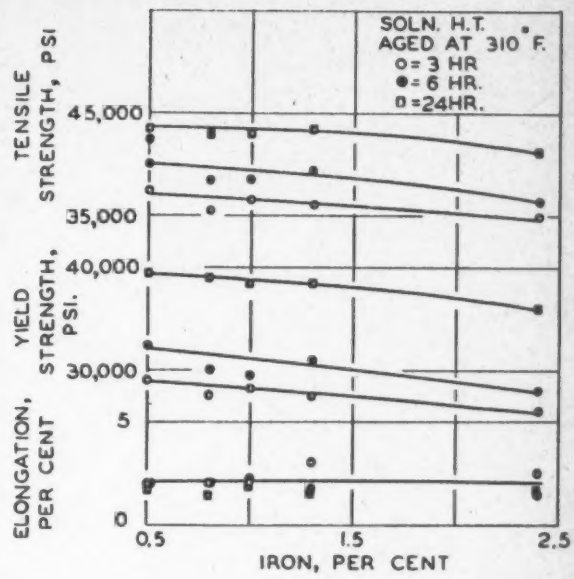

Fig. 21—Effect of iron on the properties of test bars solution treated and aged at 310° F.

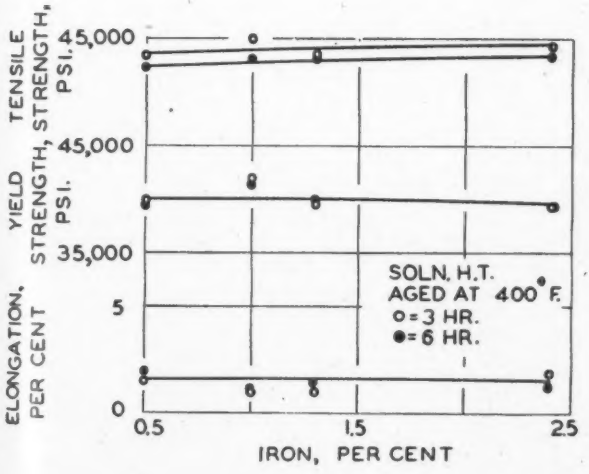

Fig. 22—Effect of iron upon solution treating and aging at 400° F.

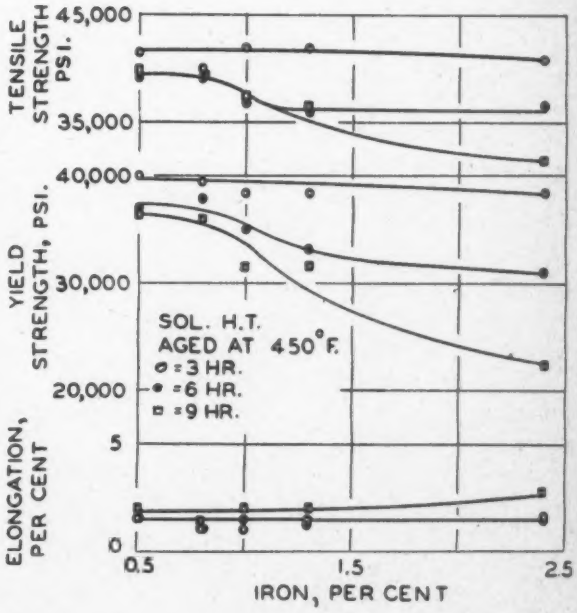

Fig. 23—Effect of iron upon solution treating and aging at 450° F.

Table 7

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.15
Silicon	5.04
Magnesium	0.52
Manganese	0.58
Iron	0.76
Nickel	0.02
Zinc	0.03
Chromium	0.20
Titanium	0.08
Aluminum	Balance

Table 8

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.33
Silicon	5.17
Magnesium	0.33
Manganese	0.03
Iron	0.77
Nickel	0.02
Zinc	0.23
Chromium	0.10
Titanium	0.10
Aluminum	Balance

Table 9

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.68
Silicon	4.90
Magnesium	0.53
Manganese	0.37
Iron	0.48
Nickel	0.03
Zinc	0.25
Chromium	0.006
Titanium	0.005
Aluminum	Balance

the alloy, although the significance of the slight changes in slope of these curves is dubious.

According to the plot in Fig. 20, iron of over one per cent appears to impair the strength properties of F150.5 alloy in the as-cast condition. However, the data used in this plot were obtained from one to 3 days after casting. Spare tensile bars of the alloy containing 2.4 per cent iron were pulled after aging 18 days at a room temperature of 75-80° F.

Mechanical Properties

Tensile strength averaged 26,100 psi., yield strength 17,700 psi., elongation 1½ per cent, and the Brinell hardness was 72. Since these properties compared favorably with those obtained on the initial alloy, it seemed advisable to check the room temperature aging characteristics of the intervening alloys to note any change in hardness which would indicate a substantial change in tensile properties.

Sections of test bars which had been retained for metallographic study were utilized for hardness measurements. The Brinell hardnesses (500-kg. load, 10-mm. ball, 30 sec.) shown in Table 10 were obtained.

It would appear that no subsequent hardening occurred in the alloy containing one per cent of iron or less. The higher iron alloys definitely hardened during the period of observation.

Final mechanical properties of these alloys in the as-cast temper are very close to those containing low iron, and indicate that it has no effect upon the alloy in this temper except to inhibit the precipitation of a hardening constituent under the casting and cooling conditions employed.

The only change in microstructure occurred in the high iron alloy. Figure 24 shows plates of primary alpha (FeSi) found in the alloy with 2.4 per cent of iron.

Fig. 24—As-quenched alloy with 2.4 per cent iron. Primary alpha Fe-Si (plates), silicon (half tone). Etchant, 1 per cent HF. 300X.

Effect of Manganese

Absence of a deleterious effect of iron on this alloy is believed to be due at least in part to the presence of manganese. This fact has been noted previously in the literature[7,8,9] although no systematic study to substantiate this claim has been forthcoming. Therefore, it was decided to attempt to prove this fact by determining the relative effects of manganese and iron in various combinations with each other.

Relative Effects of Iron and Manganese. The possibility that manganese may play an important role in the development of superior mechanical properties in F150.5 alloy led to the following investigation. A quantity of ingots of the analysis shown in Table 11 was procured.

Several ingots were melted and the mechanical properties in various tempers obtained. This metal was then remelted and manganese added to raise this element to 0.50 per cent, and properties redetermined. The metal was melted a third time and iron was added to increase it to 0.93 per cent, and again physical properties were determined.

These three melts, then, were used to obtain the properties of an F150.5 alloy containing low iron (0.34 per cent) and low manganese (0.01 per cent); low iron (0.34 per cent) and high manganese (0.50 per cent); and high iron (0.93 per cent) and high manganese (0.50 per cent) in that order.

Another set of ingots from the initial charge was melted and iron added first to raise it to 0.83 per cent. After the usual physical tests, the metal was remelted and manganese added, which raised this element to 0.65 per cent.

Second Melt

The second pair of melts indicated the properties to be obtained on the same F150.5 alloy when it contained high iron (0.83 per cent) with low manganese (0.01 per cent) and again high iron (0.83 per cent)

Table 10

ALUMINUM ALLOY HARDNESSES

Iron Content per cent	*Aged at Room Temp., days*	*Brinell Hardness No.*
0.48	1-4	74-74
	70	74
0.80	1-4	72-74
	60	74
1.01	1-4	74-74
	40	74
1.32	1-4	65-65
	30	74
2.40	1-4	61-61
	18	72-74-72

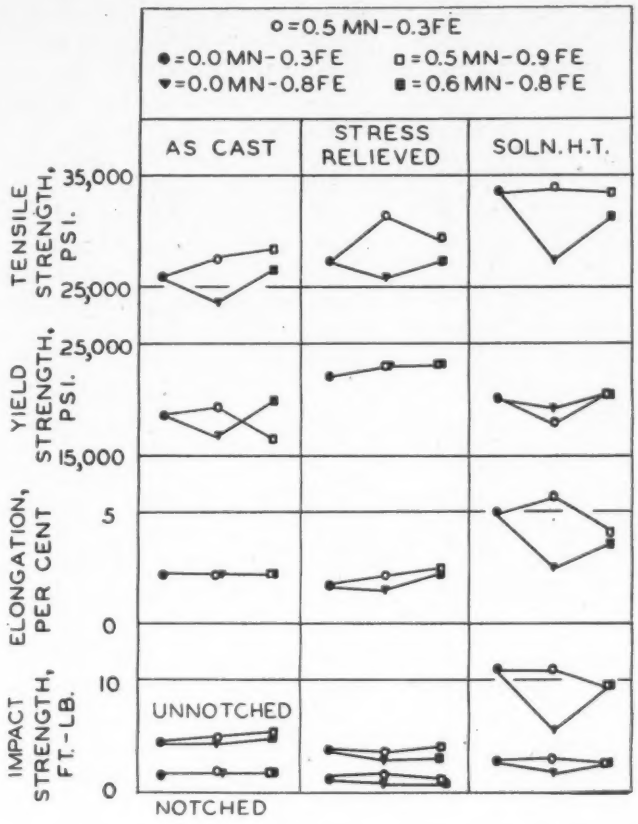

Fig. 25—Effect of various manganese-iron combinations on properties in the as-cast, stress relieved, and solution heat treated tempers.

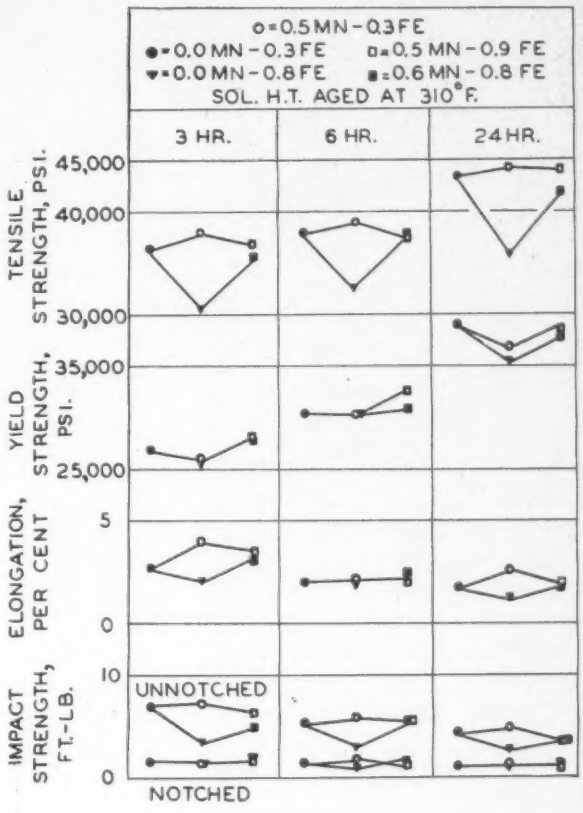

Fig. 26—Effect of various manganese-iron combinations on properties of specimens solution heat treated and aged at 310° F.

with high manganese (0.65 per cent).

The results of all five heats are plotted in Figs. 25, 26 and 27. It is readily apparent that the only alloy having inferior properties is the one with high iron and no manganese. When manganese is added to this alloy a distinct improvement in properties is noted which makes them generally equivalent to those of the initial alloy with low iron and low manganese.

Arriving at substantially the same set of properties by this circuitous method is considered an excellent check on the fact that iron is a much less critical element than manganese in this alloy. Iron under one per cent has essentially no effect if about 0.5 per cent manganese is also present. In fact, manganese appears to effect a slight but persistant improvement in even the low iron alloy.

Further, these data indicate that 0.5 per cent or 0.6 per cent iron may well be the maximum permissible if low manganese is also re-

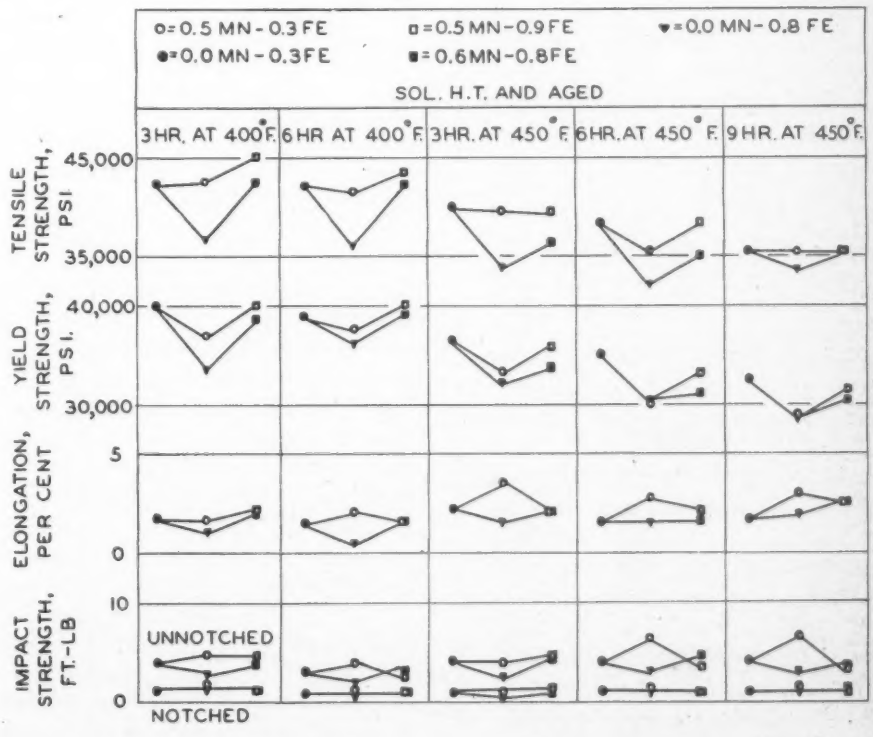

Fig. 27—Effect of various manganese-iron combinations upon solution treating and aging at 400° F. and 450° F.

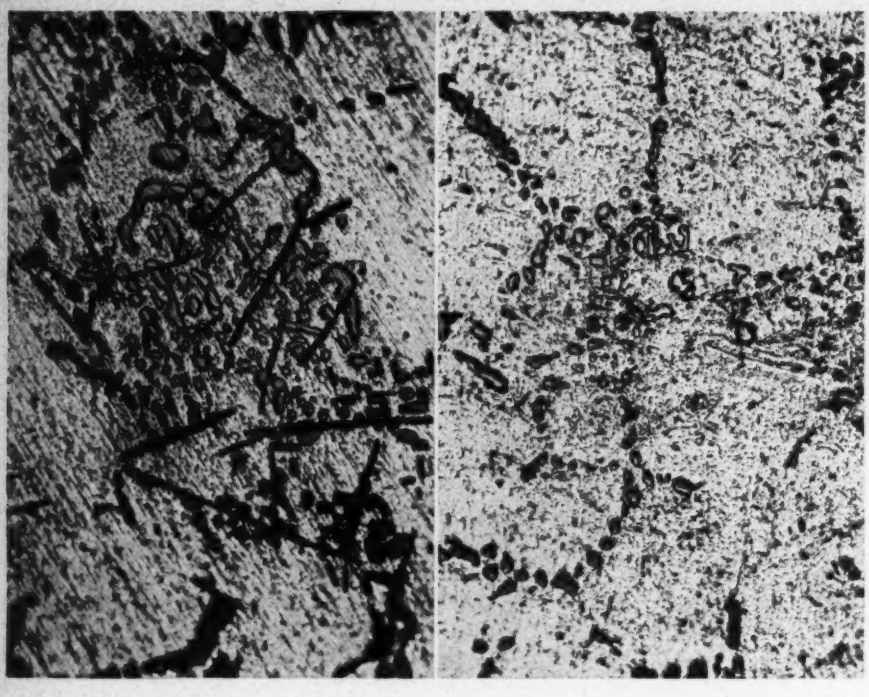

Fig. 28—Effect of iron on microstructure (as-quenched). Etchant, 1 per cent HF. 300X. Left—Initial alloy with 0.34 per cent iron. Spheroidized silicon in alpha aluminum matrix. Right—Same alloy with 0.83 per cent iron. Beta Fe-Si (needles) associated with spheroidized silicon.

quired. In this regard the present specifications appear justified, since with more than 0.5 per cent iron the beta (Fe-Si) phase field is entered with its attendant deleterious effect on mechanical properties.

Table 11

ALLOY COMPOSITION

Component	*Per Cent*
Copper	1.35
Silicon	5.52
Magnesium	0.55
Manganese	0.01
Iron	0.34
Nickel	0.01
Zinc	0.04
Chromium	0.10
Titanium	0.05
Aluminum	Balance

Table 12

ALLOY COMPOSITIONS

Component	*Initial Alloy, per cent*	*Adjusted Alloy, per cent*
Copper	1.35	1.35
Silicon	5.52	5.52
Magnesium	0.55	0.55
Manganese	0.01	0.50
Iron	0.34	0.81
Nickel	0.01	0.24
Zinc	0.04	0.37
Chromium	0.10	0.10
Titanium	0.05	0.05
Aluminum	Balance	Balance

A distinct change in microstructure accompanies the observed variation in properties. Figure 28 shows both the initial microstructure and the needlelike phase which occurred in the F150.5 alloy containing 0.83 per cent iron and 0.01 per cent manganese. No such structure could be located in the initial alloy, although an Al-Fe-Si compound must exist[10]. It is apparently too finely dispersed to be readily detected microscopically.

When 0.65 per cent manganese is added to the high iron alloy, the needlelike beta (Fe-Si) phase is suppressed and the common scriptlike habit of secondary alpha (Fe-Si) is substituted (Fig. 29). This same constituent is found in the low iron alloy containing 0.5 manganese. Heat treatment does not appear to affect the form or occurrence of these phases, and they show little tendency to go into solid solution.

Composite Effect of Greater Percentage of Minor Alloying Elements in F150.5 Alloy. Upon completion of the various investigations previously described it became apparent that an equally satisfactory specification for this alloy could be utilized that was more generous in regard to the investigated elements. The resulting alloy would have equivalent properties to one of high commercial purity. A series of tests was performed with alloys of the compositions shown in Table 12, produced from the same lot of metal and adding desired quantities of iron, manganese, nickel, and zinc to one of the melts.

Results of this test are plotted in Fig. 30. It is apparent that there is essentially no difference between these alloys in regard to mechanical properties except for the fact that the more highly alloyed material overages more rapidly at a temperature of 450° F.

As may be noted from the curves previously given in this paper, this phenomenon of accelerated overaging appears to be related to the total quantity of alloying elements rather than being an effect ascribable to any one element. All F150.5 alloys overage at temperatures of 450° F. independent of the degree of purity, but an extra per cent or two of other alloying elements increases this overaging.

It should be emphasized that the tendency for the more highly alloyed F150.5 alloys to overage at the temperatures of 450° F. after solution heat treatment is not necessarily a disadvantage.

Heating at these relatively high

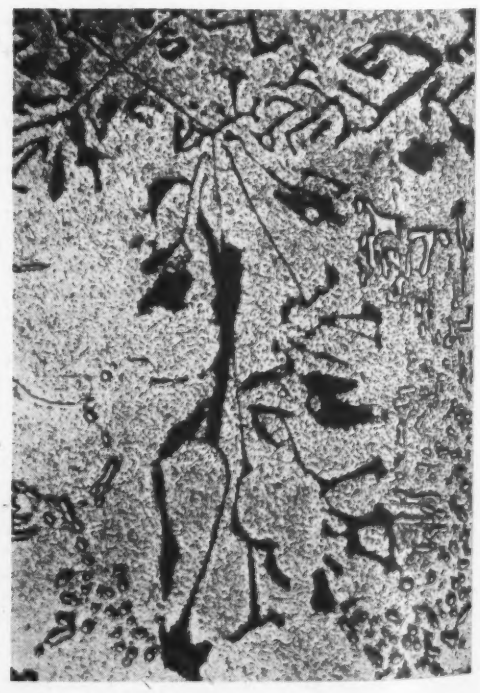

Fig. 29—Structure of alloy shown in Fig. 28 (right) when alloyed with 0.65 per cent manganese. Secondary alpha Fe-Si (script) and spheroidized silicon. Etchant, 1 per cent HF. 300X.

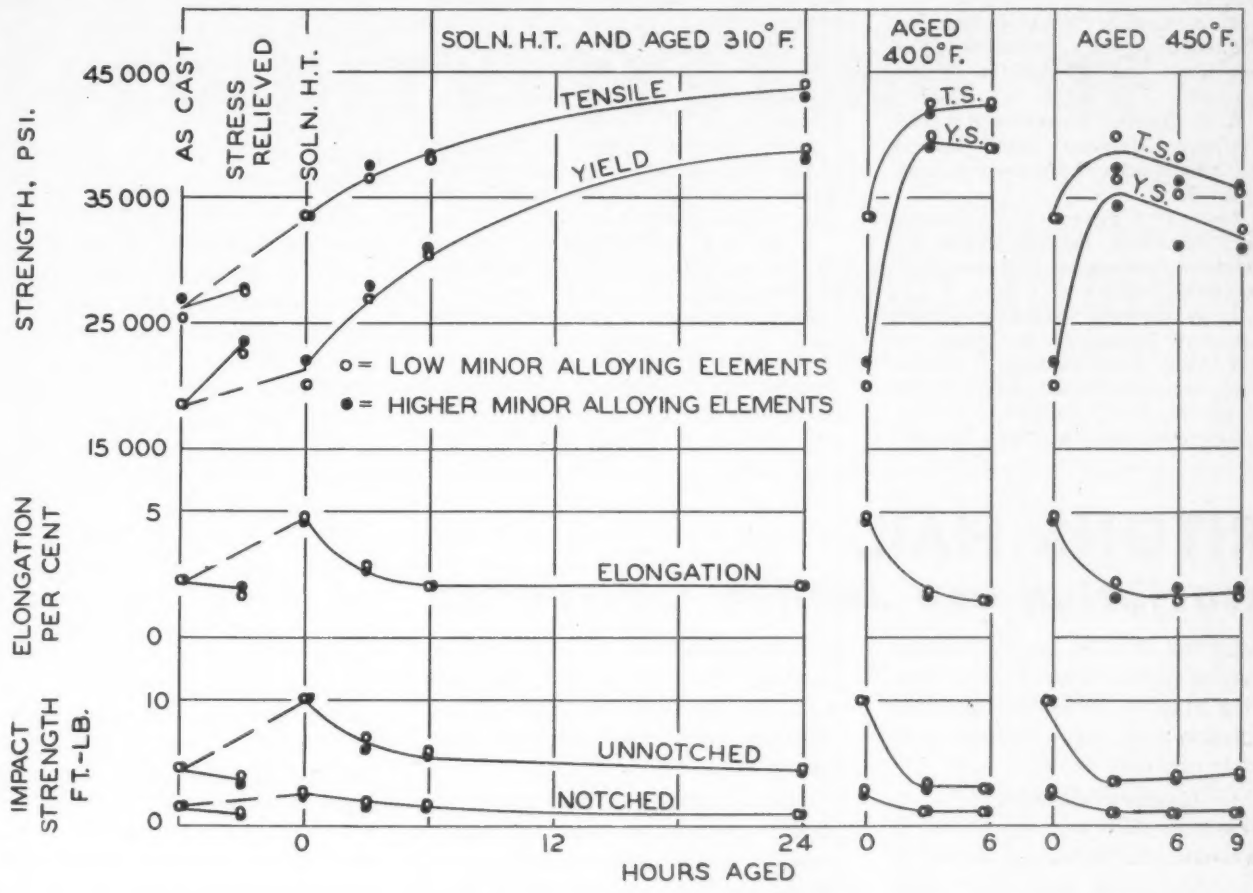

Fig. 30—Composite effect of higher percentages of minor alloying elements on an F150.5 alloy of high commercial purity.

temperatures is practiced to stabilize the alloy so that further dimensional changes at intermediate temperatures will not occur, and to relieve residual internal stresses due to quenching. Alloys which overage more rapidly may, therefore, be stabilized in shorter heat treating periods.

Summary

The effects of casting conditions and of varying amounts of magnesium, manganese, iron, nickel, and zinc have been determined on the sand cast and heat treated properties of representative commercial samples within the range of F150.5 aluminum alloy.

Pouring temperatures greatly affect the resulting grain size and physical properties. Overheating the alloy has no influence on the resultant grain size or mechanical properties providing excessive gassing has not occurred and the alloy is cooled to the optimum casting temperature. In general, the alloy should be cast as cold as possible: 1250° F. maximum temperature for standard test bars.

Magnesium is the most critical element in this alloy in its effect on mechanical properties. It tends to oxidize selectively upon melting and remelting, and the loss must be made up. It renders the alloy susceptible to heat treatment, and increasing amounts produce stronger less ductile castings.

Nickel under 0.30 per cent has essentially no effect on the mechanical properties investigated. Zinc is likewise harmless in amounts up to one per cent. Iron may or may not be deleterious, depending upon the manganese content of the alloy.

Probably no more than 0.6 per cent iron can be safely tolerated if manganese is absent. If about 0.5 per cent manganese is also present, up to one per cent of iron will have no effect. Since manganese also improves the properties of the alloy with low iron, it appears desirable to produce this alloy with at least 0.3 per cent manganese.

Since iron pickup is a constant foundry problem, such insurance against inferior properties due to comparatively high iron should be of interest to the producer and consumer of castings alike. Probably manganese should be specified as a range of 0.30 to 0.70 per cent, while the iron content in castings should then be limited to a maximum of one per cent.

Acknowledgment

The work reported in this paper represents part of a program of research conducted at the Central Research Laboratory of the American Smelting and Refining Co. for its Federated Metals Div.

The guidance and interest of Dr. A. J. Phillips and A. A. Smith, Jr., is gratefully acknowledged. The author is indebted to Miss Doris Marshall for her assistance in carrying out the laboratory work.

References

1. Recommended Practices for the Sand Casting of Non-Ferrous Alloys,

American Foundrymen's Association, 1944, p. 121.

2. R. A. Quadt, "Cast to Size Impact Specimens for Aluminum Sand Casting Alloys," ASTM *Bulletin*, August, 1945, p. 24.

3. R. A. Quadt, "Properties of a General Purpose Aluminum Sand Casting Alloy," *Aluminum and Magnesium*, June, 1945, p. 18.

4. Process Control of Aluminum Foundry Procedure, Progress Report No. 1, Society of Automotive Engineers, February, 1945, p. C4.

5. T. W. Bossert, "Effect of Melting and Pouring Conditions on Quality of No. 12 Alloy Sand Castings," TRANSACTIONS, American Foundrymen's Association, vol. 36, p. 427 (1928).

6. RECOMMENDED PRACTICES FOR THE SAND CASTING OF NON-FERROUS ALLOYS, American Foundrymen's Association, 1944, p. 107.

7. W. Bonsack, "Effect of Alloying Elements on Aluminum Casting Alloys," TRANSACTIONS, American Foundrymen's Association, p. 789 (1944).

8. W. Bonsack, "Effects of Minor Alloying Elements on Aluminum Casting Alloys—Part II," ASTM *Bulletin No. 124*, October, 1943, p. 41.

9. H. W. L. Phillips and P. C. Varley, "The Constitution of Alloys of Aluminum with Manganese Silicon, and Iron," *Journal*, Institute of Metals, vol. 69, 1934, p. 317.

10. A. G. C. Gwyer and H. W. L. Phillips, "The Constitution of Alloys of Aluminum with Silicon and Iron," *Journal*, Institute of Metals, vol. 38, 1927.

BRITONS HAIL
Association and Jubilee Convention

SALUTING A.F.A. in its Golden Jubilee year, *Foundry Trade Journal*, for May 30, 1946, directs to the Association a message in which every member can take pride:

Congratulations

"When in 1896, a group of enthusiasts created the American Foundrymen's Association, they did more than provide an organization for the collection and dissemination of technical knowledge, they gave a new significance to the word 'foundryman.' Before this date, though the word existed in the United States, it was virtually obsolete in this country. We are not, and never have been, particularly enamoured of the word, but we are conscious of the fact that where constant usage is invariably directed in a decent and respectable sense, time will accord it the status so gained. Thus for 50 years the American Foundrymen's Association, with which body we have been proud to be associated for a quarter of a century has constantly added lustre to the escutcheon of the industry. It was the prototype upon which the Institute of British Foundrymen was built. Co-operation between the organizations has been continuous since the late Mr. A. O. Backert, the then president of the A.F.A., visited this country in 1919. The next year saw at the Blackpool Convention the presentation of the first American Exchange Paper, and every year since that time this excellent system has continued. Realizing the benefits to be derived from the organization of Branch [chapter] activities, the A.F.A. emulated the Institute in 1934. So great a success has followed its launching that the total membership is now over 8,000.

"The British foundry industry is greatly indebted to American enterprise. To its credit must go many major developments in mechanical moulding and sand control. Modestly, we express the opinion that if we have not been particularly outstanding as creators of foundry developments, we have at least been apt pupils. Between the two wars, many of the presidents and high officials paid visits to this country, and the personal contacts so established have proved to be of the greatest value in oiling the wheels of co-operation during the last war.

"The conference held in Cleveland was of truly gigantic dimensions, the attendance being of the order of 20,000. The Mayor of Cleveland officially designated this manifestation as "Foundry Week," and we doubt if ever the inhabitants of any city in the world have been made so conscious of the importance of our industry. National recognition of the importance of the event was given by the receipt of a telegram from President Truman. It is a matter of regret that the celebrations came at a time when the aftermath of war with its paucity of transport, currency restrictions and ragbag wardrobes, limited international co-operation to the minimum. However, the 'token' delegation, headed by Mr. Tom Makemson [Secretary, Institute of British Foundrymen] adequately expressed the sincere admiration felt by European foundrymen for the enterprise and energy which has placed the American Foundrymen's Association on the highest level amongst co-operative technical efforts.

"The time is appropriate to express the gratitude of the foundry world to those two great pioneers Dr. Moldenke and Mr. John A. Penton, who possessed the vision to realize that there existed a need for an organization which would plough science into their industry. A fertile field resulted, and from its seeds the world's factories have gained immeasurable benefits.

"The A.F.A. is now directed by a virtually new staff. To them and their successors go our best wishes. To the members, President and Council [Board of Directors] of the American Foundrymen's Association we send our heartiest congratulations on the culmination of fifty years of honest and enlightened service to a worthwhile basic industry."

Following his return to England, Mr. Makemson added another pleasant post-Convention note, in a letter to the National Office:

"Now that we are back I think I ought to tell you that we had a most interesting time. It was a very useful trip and, in addition to its usefulness, we all of us enjoyed it very much. The success of the trip was, of course, due entirely to the help and co-operation we received from our American friends, and the main purpose of this letter is to thank the American Foundrymen's Association for inviting us to attend the Conference, and also for all the help with regard to our accommodation and to our post-Conference trip. We are very much indebted to all our friends in the A.F.A. Please accept our sincere thanks."

Chapter Furthers City Educational Bond Issue

FOUNDRY EDUCATIONAL FACILITIES will be available in a new trade school to be established in Cleveland as part of an educational project for which a municipal bond issue of $2,250,000 recently won approval, furthered by active support of Northeastern Ohio A.F.A. chapter through its educational committee.

FLUIDITY TESTING OF FOUNDRY ALLOYS

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Naval Research Laboratory
Washington, D. C.

Fluidity testing of foundry alloys is a subject of importance to the foundry industry because it is a method which can be used to evalute the casting characteristics of alloys and which may be employed for quality control in the shop. Many investigations on fluidity have been made but few investigators have employed the same test piece. An objective of the Committee on Fluidity Testing of the American Foundrymen's Association is to determine if a single, standard fluidity test which is reasonably suitable for all foundry alloys can be adopted by the industry so that data from many sources can be compared directly. Accordingly, published work on fluidity has been appraised by the author and certain recommendations are offered.

TWO REASONS for fluidity testing are: First, fluidity of new or unfamiliar alloys may be determined so that the person responsible for casting operations can choose the one with the best fluidity among several alloys which otherwise may be equally suitable for the specific application.

Some evidence exists[105] which indicates that many alloys have approximately equal fluidity when they are heated an equal degree above their respective liquidus temperatures. However, this point has not been proved conclusively and more data are necessary for the information of foundrymen. There is a definite need for fluidity testing in the laboratory to aid the development of better foundry practice.

Second, fluidity testing on the shop floor is a means of quality control to which some foundries have not given careful consideration. Some foundrymen believe that fluidity testing is strictly a laboratory expedient and that it has no place in a production shop. Certainly, in foundries where no castings having thin sections or intricate shapes are poured, or where misrun castings are never encountered, it would be a waste of time to train personnel for reliable fluidity testing.

Likewise, in certain non-ferrous foundries where temperature measurement is not difficult, fluidity testing assumes minor importance. However, in shops where metal is used at temperatures above 2200° F. (1205° C.) for the pouring of castings which are susceptible to misruns, it is believed that routine fluidity testing can be employed with profit. In support of this statement, it may be said that a fluidity test has been used with marked success to prevent the occurrence of misrun steel castings in the foundry of the U. S. Naval Research Laboratory.

After a period of observation, it was learned that if the length of the fluidity spiral poured with metal taken from the direct-arc furnace is less than 20 in., intricate castings are apt to be misrun; that if the length is more than 26 in., misruns do not occur, and that if the length is 20 to 26 in., misruns occur occasionally. These observations apply to normal operation in the pouring of miscellaneous shop castings at the U. S. Naval Research Laboratory, and the limiting values would be different in another foundry where ladle preheating, ladle capacity, pouring time, and other conditions would be different.

Fluidity Defined

Fluidity is the term used in this paper to express the ability of metal to flow. It is the resultant effect of several physical conditions which govern the solidification of molten metal as it flows in a mold. Fluidity is not a true physical property of the metal and is difficult to define exactly.

A foundryman can express it most easily by means of a comparison. For example, metal is said to have adequate fluidity for a specific casting application if it flows freely through the gates and fills the mold completely so that a casting is formed without misruns or cold shuts.

Fluidity Evaluated. Many troublesome variables would have to be considered if an attempt were made to evaluate fluidity on a truly physical basis, as heat transfer, fluid flow,

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viscosity, mechanics of solidification, film formation, surface tension, gas evolution, and suspended non-metallic materials are operative in determining this complex quantity.

Acordingly, the only convenient method of evaluating fluidity is an empirical one. That is, carefully standardized test conditions must be established and rigorously reproduced from test to test. Even when this is done, the values obtained are only relative and can be used only by observed correlation with casting practice for control purposes or for comparison of one metal with another on an arbitrary basis.

Often Investigated

Many investigators have studied fluidity and have reported their findings in the literature of foundry technology. Figures 1 through 5 illustrate some of the test pieces which have been used. A comprehensive bibliography[1-60] on fluidity of metals covering the period from 1902 to 1935 was prepared by the British Iron and Steel Institute.

The preponderance of attention in recent years has been given to ferrous alloys, and the work of British investigators has been particularly noteworthy. These reports[66, 67, 75, 76, 77, 78] and other valuable contributions on fluidity [61-65, 68-74, 79-105] since 1935 are also listed in the bibliography at the end of this paper.

Thus, most of the factors concerning the condition of the metal and their effects upon fluidity have been considered at one time or another. The unfortunate feature of all this work is that many of the investigators have adopted totally new test pieces or have so altered previously used test pieces that it is not possible to compare data.

Progress usually comes from changes and alterations and these changes have served a useful purpose. However, it appears desirable to agree upon a standard test piece and testing procedure so that foundrymen can speak a common language of fluidity and can compare notes on the fluidity of their alloys. In this manner, a rational correlation between measured fluidity and casting practice can be made in a relatively short period. Adoption of such a standard throughout the foundry industry is the objective of the Fluidity Committee of the American Foundrymen's Association.

It is not meant to imply that one test piece and one testing procedure are necessarily best for all foundry alloys, but it is believed that some concessions, made in the interest of standardization, would be beneficial to the interests of all. Therefore, this paper is written to present a survey and critical appraisal of published information concerning the variables of fluidity testing.

Aspects Considered

In the discussion of these variables which follows, consideration is given to sensitivity and reproducibility for laboratory tests and to simplicity for shop practice. Emphasis is placed on the requirements of fluidity tests for high-melting-point alloys, but special requirements for certain of the lower-melting-point alloys are not overlooked.

Ideal Conditions for Fluidity Testing. In practically all of the tests which have been used to evaluate fluidity of molten metals, the same basic method has been followed. Metal is caused to flow into a chan-

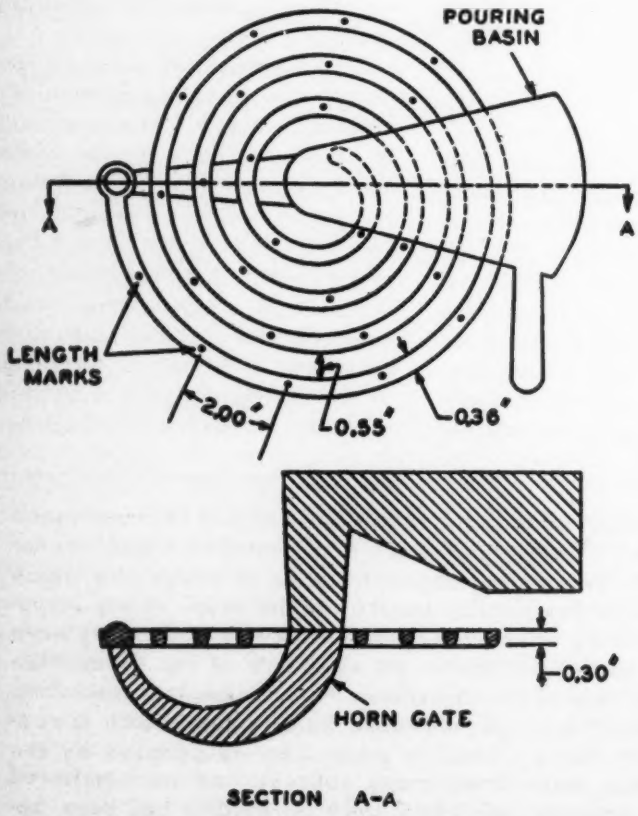


Fig. 1—Fluidity pattern assembly (Saeger, Krynitsky).

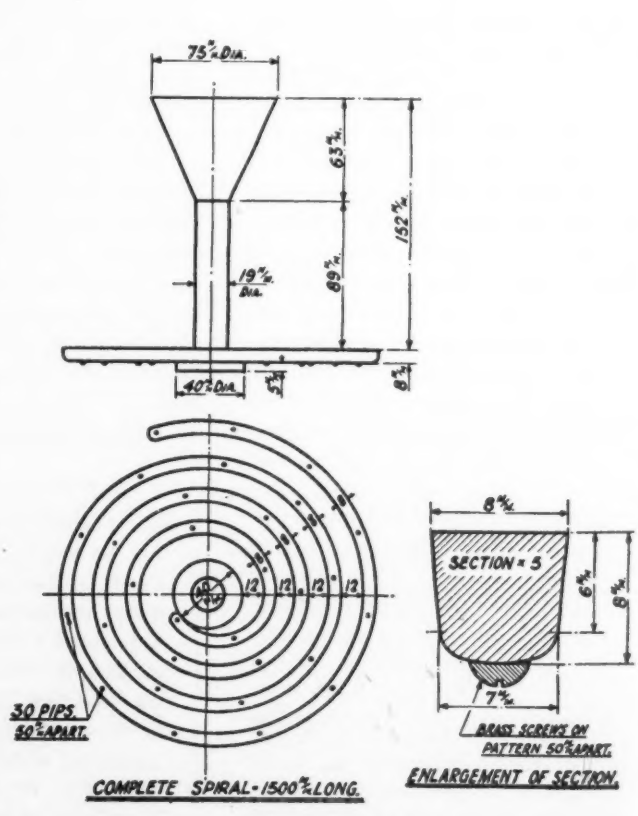


Fig. 2—Spiral for fluidity test (Greaves).

nel of relatively small cross-sectional areas for a distance determined by the rate at which the mold extracts sufficient heat to cause solidification of the metal and to stop movement of the stream. The length of flow is taken as the measure of fluidity. As with any test, sensitivity and reproducibility are necessary if the test is to be useful.

For a fair degree of sensitivity, the test piece must be designed with a definite relationship among the factors of force acting to drive the metal through the flow channel, the dimensions of the flow channel, and the thermal characteristics of the mold material. Regardless of the fluidity of the metal, if the proper relationship is not obtained, the metal in one instance may be forced through the full length of the channel or, in another, may be frozen without having flowed an appreciable distance. In either extreme case the test is meaningless.

If the fluidity test piece is designed for adequate sensitivity, duplication of test conditions within close limits from test to test is still a major problem. Ideally, the conditions for optimum reproducibility are as follows:

1. The force exerted upon the metal at the point of entry to the flow channel should be constant.

2. No other variable force such as that of gravity, due to variations in pouring rate or metal head, or of expanding gases should be imposed upon the metal during its period of flow.

3. The conditions of heat transfer must remain constant from test to test.

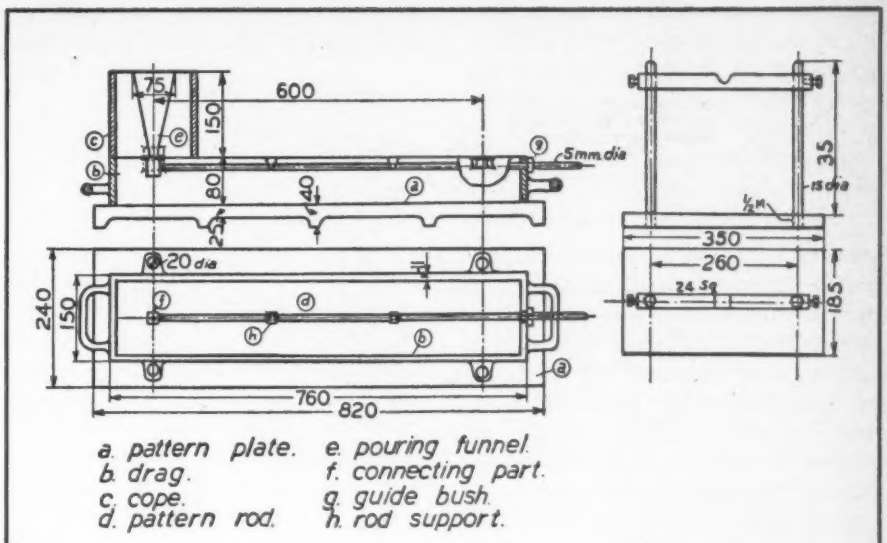


Fig. 4—Spoon test for determination of the running capacity of liquid metal (Ruff).

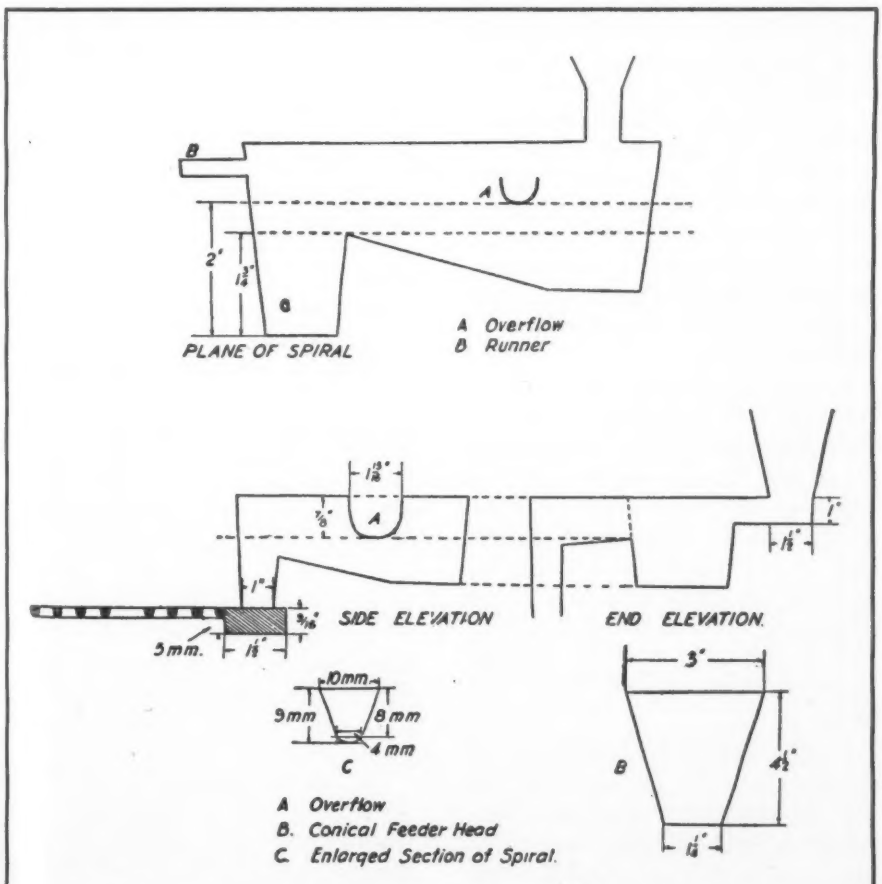


Fig. 3—Fluidity test piece (Andrew, Percival, and Bottomley).

In practice these ideals are difficult to attain and some compromise must be made. These compromises are discussed in the paragraphs which follow.

Shape and Dimensions of the Flow Channel. In one of the earliest investigations on fluidity, West[1] used a casting in the form of an elongated wedge. This type of test casting is still used in some foundries. However, most of the reported data were obtained by the employment of flow channels with uniform shapes and dimensions throughout their lengths. Square, rectangular, circular, half-circular and trapezoidal sections have been used.

General Indications

Since the practical value of a fluidity test is mainly relative, it appears that the cross-sectional shape makes little difference except for the ease with which the pattern is molded. From this standpoint, a circular section is not satisfactory. Unless a straight rod is used, a circular section must be molded with a parting line and the danger of mismatches is always present.

Because the complete impression of the flow channel can be made in one-half of the mold, and because

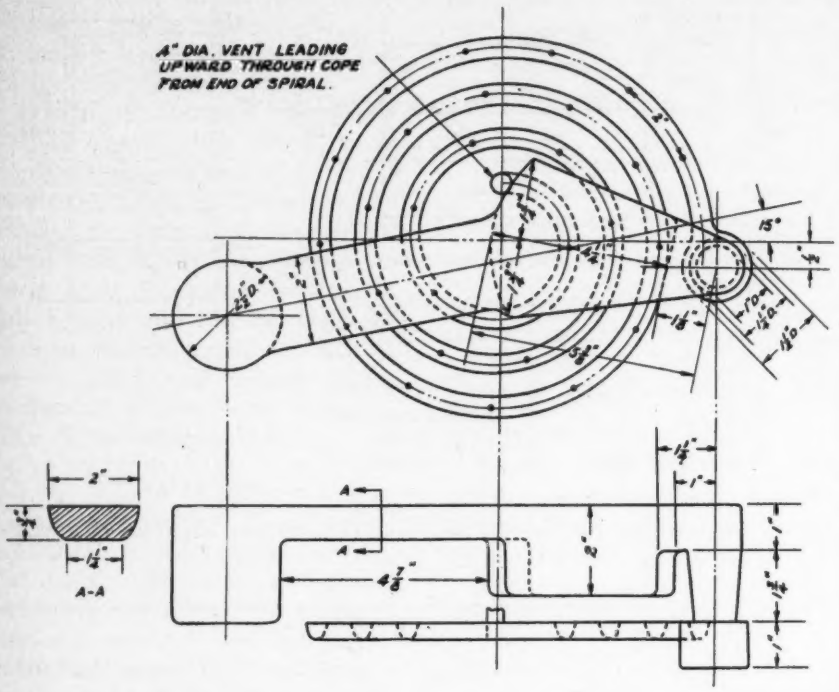


Fig. 5—Fluidity spiral test piece (Taylor, Rominski, and Briggs).

of the ease with which the pattern may be drawn from the sand, a half-round or trapezoidal section is believed to be most practical for the flow channel.

Dimensional Variations

Cross-sectional dimensions of the flow channel can be varied within certain limits in accordance with the height of the down gate and the thermal characteristics of the molding material. Saeger and Krynitsky[28] used a rounded, trapezoidal flow channel with an area of approximately 1/12 sq. in. The approximate cross-sectional area of the flow channel used by Andrew, Percival and Bottomley[67] is 1/11 sq. in. Ruff's[65] channel is circular and has a cross-sectional area of approximately 1/30 sq. in.

Taylor, Rominski and Briggs[89] made their tests with a flow channel having a rounded, trapezoidal shape and an area of approximately 1/7 sq. in. Greaves[66] also used a rounded, trapezoidal flow channel with a cross-sectional area of approximately 1/9 sq. in. Although the foregoing investigators made their studies upon ferrous alloys in sand molds, it has been reported to the writer that satisfactory fluidity tests have also been made upon aluminum and copper-base alloys with the test piece of Taylor, Rominski and Briggs.

Ruff[65] did not use the fluidity test proposed by Saeger and Krynitsky[28] because he believed that the flow channel was too large to avoid turbulent flow of the metal. Whether or not turbulent flow is deleterious to the test is debatable. However, in view of the apparently satisfactory results of several investigators who used the larger flow channels, it is believed desirable to establish the cross-sectional area of a standard fluidity test channel between 1/12 and 1/7 sq. in.

Length of the flow channel must be such that solidification of the most fluid metal to be tested occurs before the stream reaches the full length of the cavity. This, in turn, is determined by the cross-sectional area of the flow channel and by other factors which have been stated previously, namely, the thermal nature of the mold material and the pressure head exerted upon the metal.

Of the test pieces mentioned in connection with the discussion of the cross-sectional area of flow channel, those used by Saeger and Krynitsky[28], Greaves[66], and Taylor, Rominski and Briggs[89] are all approximately 60 in. long. That used by Ruff[65] is approximately 24 in. long. If the recommendations regarding cross-sectional area are to be followed, it would appear necessary to establish a length of flow channel of approximately 60 in.

Spiral Flow Channels vs. Straight Flow Channels. In most of the test pieces designed for measurement of fluidity a spiral configuration of the flow channel has been adopted for reasons of simplicity in molding. Ruff[65] used a straight flow channel but the length is relatively short, 24 in. as compared with a length of approximately 60 in. for the other test pieces which have been mentioned.

Molding Errors

If the test piece is to be molded in a two-part flask, it is almost essential that the pattern be mounted on a board. Obviously, if the board is more than 60 in. long, as is required when the previously recommended flow channels are made straight, much more opportunity exists for distortion during handling and storage of the pattern or during ramming of the sand than if the flow channel is formed as a spiral.

Even though the cross-sectional dimensions are assumed to be as large as ½x½ in., a distortion of the board of as little as 0.025 in. causes a variation of 5 per cent in the cross-sectional area. Surely, if only one condition of the test is subject to errors of this order, close control of other unavoidable errors would not be sufficient to make the test reproducible within reasonable limits.

Another point in favor of the spiral flow channel is the matter of levelling of the mold. In any laboratory determination where the highest precision is desirable, test molds should be levelled carefully, regardless of the design of the mold. However, for quality control in the shop, it appears desirable to make the test as insensitive to levelling as possible. In a case where one or more turns of the spiral are filled with molten steel, variations in pressure head caused by a slight inclination of the mold may be very nearly self-compensated.

For control purposes at the U. S. Naval Research Laboratory, the spiral-type fluidity mold is levelled only by sight. It is placed upon a thin layer of sand in the bottom of a wheelbarrow. When it is desirable to make a fluidity test, the mold is

wheeled to a convenient position and is poured without further preparation. This freedom would not be possible if a test piece with a straight flow channel were employed.

Other advantages of the spiral flow channel are that standard flask equipment may be used and the mold is small enough to be handled with ease.

Material of the Mold for Fluidity Testing. Several of the arguments set forth in the foregoing paragraphs have been made on the assumption that green sand is the most desirable molding medium. This point deserves some discussion.

If a choice is to be made between a permanent mold of cast iron or steel and a sand mold for fluidity testing, there appears to be little room for argument. Permanent molds have the one advantage of offering a better opportunity for constancy of dimensions of the flow channel. However, if scaling and pitting from repeated use are to be avoided when high-melting-point alloys are tested in the mold, a mold dressing must be applied.

Effect of Dressings

Since heat is carried away rapidly by a metallic mold, variation in the thermal characteristics of the dressing causes a profound effect upon the time necessary to extract enough heat from the flowing metal to cause it to solidify, and therefore upon the indicated fluidity. Moreover, the presence of any gas-forming material in a mold dressing is a probable cause of erroneous test results since a permanent mold has no permeability and entrapped gas causes unpredictable retardation or acceleration of the metal flow.

The choice between green and dry sand molds or baked core-sand assemblies is more difficult to make. An obvious difficulty with core assemblies is warpage of one-half of the mold in relation to the other half which occurs during baking. Unless the cores are baked as assembled in supporting frames which are retained in position until the test mold has been used, this warpage is apt to cause "run-outs" and unreliable test results.

Such difficulties are not experienced in the use of straight flow channels if corrosion-resistant straight rods are baked in the sand and are removed later, as was done by Kron and Lorig[79] who used a modification of Ruff's method for their fluidity studies.

Green sand molds are more economical than baked sand molds, and several investigators have expressed the view that they are entirely satisfactory if certain precautions are observed. First, the bond strength of the sand must be adequate so that sand is not eroded by the flowing metal. Second, the sand must be sufficiently permeable so that the steam formed by the rapid heating of the water in the molding sand can escape easily to the atmosphere and does not cause pressure to be exerted upon the metal.

Sand Moisture Content

In this connection, it is deemed advisable to provide an ample vent at the end of the flow channel as a factor of safety to prevent the development of gas pressure ahead of the flowing metal. Whether or not normal variations in the moisture content of a sand have appreciable effects upon the chilling action of the mold has been considered by several investigators. Curry[22] reported that variations of from 3 to 7 per cent appeared to make little difference in the measured fluidity.

Some differences were ascribed to variations of the moisture content of the molding sand by Saeger and Krynitsky[28].

Greaves[66] stated that moisture content of the sand seems to have little effect upon chilling of the metal unless it has flowed over a considerable area of the mold cavity. Taylor, Rominski and Briggs[89] found no significant differences in fluidity as the moisture content of the sand was changed.

If one is inclined to prefer a baked sand mold on the basis of freedom from moisture, the possibility of water absorption during storage should not be overlooked; Berger[51] summarized the situation in this regard by saying that it is easier to keep the moisture of green sand constant than to maintain dryness of cores and dried sand molds.

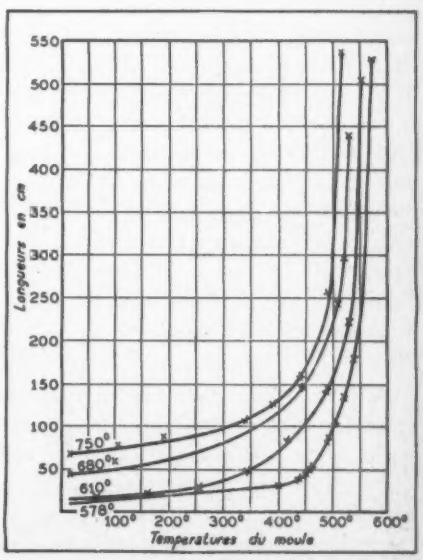
Ruff[65] conducted a study of metal flow in narrow channels to determine the effect of surface conditions of the mold cavity. For purposes of standardization of the fluidity test, a detailed treatment of these factors does not seem necessary. However, it appears desirable, for the sake of uniformity, to specify the grain size of the sand within narrow limits.

Silica sand with an A.F.A. grain size number of 80 ± 5 should be suitable if it does not contain abnormal quantities of silt and so bonded that the permeability is not less than 75 by the A.F.A. permeability test.

Temperature of Mold. The rate of heat flow from the metal varies with the initial temperature of the fluidity mold and it is to be expected that fluidity measurements would also vary with the temperature of the mold. However, Courty[29] has shown that fluidity values of aluminum-base alloys determined in cast iron molds are not increased appreciably even though the molds are heated considerably above that temperature which can be expected from climatic variations (Fig. 6). Therefore, it is believed necessary to specify only that the standard fluidity test mold be at room temperature at the time of test.

Gating Methods. Ideally, the system of gating should be so designed that metal is available at the entry of the flow channel under a constant pressure head and without appreciable inertia. Such an ideal could be achieved only by having a reservoir of liquid immediately adjacent to the flow channel with a quick-opening valve at the point of its entry, and by having provision for maintenance of a constant pressure head on the reservoir. Successful operation of a quick-opening valve in molten metal at this position in

Fig. 6—Castability of an aluminum alloy vs. mold temperature (Courty).



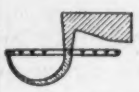
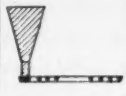
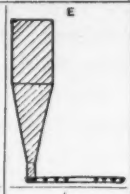
Method of Gating.	A. 		B		C		D 		E 	
Material.	Steel.	Malleable Cast Iron.	Steel.	Malleable Cast Iron.	Steel.	Malleable Cast Iron.	Steel.	Malleable Cast Iron.	Steel.	Malleable Cast Iron.
Number of experiments.	10	6	8	6	8	6	37	13	5	6
Deviation of values, %.	25	5	6	3	7	7	3	2	3	6
Maximum spiral length. Mm.	275	1091	780	1435	615	1480	940	flowed to end	745	flowed to end
Running quality ratio of steel to malleable cast iron (max.)	1 : 4·0		1 : 1·8		1 : 2·4		1 : 1·6		1 : 2·1	
Mean spiral length. Mm	147	933	647	1261	548	1230	753	1365	616	1314
Running quality ratio of steel to malleable cast iron (mean).	1 : 6·3		1 : 1·9		1 : 2·2		1 : 1·8		1 : 2·1	

Table 1—Spiral tests of steel and malleable cast iron for different gates (Ruff).

the mold is a practical impossibility. Therefore, ideal gating conditions must be approached as nearly as possible by other means.

Ruff[65] conducted some experiments in which several details of gating were varied simultaneously. Table 1, taken from his paper, is reproduced here. His test results indicate that a horn gate is not suitable for introduction of steel into the flow channel.

Carapella and Shaw[104] were also concerned about the influence of a horn gate upon fluidity tests conducted with magnesium alloys. They have reported that better sensitivity was obtained by replacing the horn gate with a vertical down gate centered over a small basin from which entry to the flow channel was made.

Metal Flow

The cross-sectional area of the sprue must be considerably larger than that of the flow channel. In this way, the velocity of the metal is low before it enters the channel and turbulence is avoided to some extent. It has been shown by Courty[29] that less than one second is required for a aluminum-silicon alloy to run 50 cm. in a chill mold containing a spiral flow channel with a cross-sectional area of approximately 1/12 sq. in.

Although the duration of flow is probably somewhat longer in a sand mold, it is still short enough to require that the sprue be filled as rapidly as possible after pouring is started. In the absence of a valve mechanism, the pressure head causing flow varies during sprue filling.

Therefore, if the sprue is comparatively small so that it is filled quickly, inconsistencies in test results from this cause are held to a minimum. It is recommended that the ratio of cross-sectional areas of down gate to flow channel be approximately six to one, although it is recognized that the ratio can be changed somewhat from this value without affecting the test perceptibly.

From Ruff's[65] work and that of other investigators, it is apparent that a large basin at the bottom of the down gate has no useful purpose in fluidity testing. It seems desirable only to have an enlargement of the sprue as a part of the channel pattern to prevent a mismatch when the sprue is molded.

Pressure Head. If the variations of the pressure head which occur during filling of the sprue be neglected and if it be considered that the sprue is kept exactly full during the period of test, the force acting to cause flow in the channel is determined by the height of the sprue and by the density of the metal. After the dimensions of the flow channel and the material of the mold have been selected, the height of the sprue must be fixed within certain limits so that the test is reasonably sensitive and even the most fluid metals which may be encountered will not flow completely through the channel.

For example, from Ruff's[65] preliminary experiments with Saeger and Krynitsky's[28] test piece (Table 1), it is apparent that the length of spiral was not sufficient with methods of gating *D* and *E*. Even with methods *B* and *C*, the malleable iron flowed very nearly to the end of the 60-in. (1525-mm.) spiral. Under these conditions, the test is not satisfactory.

Height of Sprue

The sprue should be short for convenience of molding and for prevention of sand erosion and turbulence of the metal. It is recommended that the height of the effective head be established within the range of 1 to 2½ in. if sand molds are used with flow channels having dimensions within the limits previously recommended.

All of the investigators who used flow channels of that approximate size also used pressure heads within these limits except Greaves[66]. He employed a sprue approximately 6 in. high, but did not make any provision for the maintenance of a relatively constant pressure head.

From a comparison of the densities of aluminum and magnesium with those of iron-base and copper-base alloys the question of the necessity for changing the height of the sprue is raised if one standard test piece is to be applicable to all alloys. Density is less effective in changing the conditions of test than might be expected.

Carapella and Shaw[104] used a test piece for measuring the fluidity of magnesium alloys which is similar to that developed by Saeger and Krynitsky[28] except that they substituted a simple sprue for the horn gate. Detailed dimensions are not given in their paper, but the effective height of the sprue is apparently unaltered. However, their plotted data indicate that the test is both sensitive and reproducible. Further, as has been stated, it is known by the writer that the test piece designed by Taylor, Rominski and Briggs[89] has been used satisfactorily for the measurement of fluidity of aluminum alloys.

Pouring Basins and Overflow. It is recommended that a pouring basin be provided in the standard fluidity test mold for two reasons. First, the kinetic energy of the metal being poured is largely dissipated in the pouring basin before it enters the

sprue. Second, a pouring basin is an excellent location for temperature measurement of the metal in laboratory tests. The second reason will be discussed in a subsequent section of this paper on measurement of the temperature of the metal.

Energy Dissipation

A few investigators of fluidity have taken elaborate precautions to dissipate the kinetic energy of the metal being poured before it enters the sprue. A clever device which was developed for this purpose is that used by Courty[29] who measured the fluidity of aluminum alloys in the test mold shown in Fig. 7. The sprue is stoppered by means of two fusible lead plugs. The time of melting of the plugs is regulated by the thickness.

Since lead has a much higher density than aluminum, and since the metals have practically no solubility for each other, the lead collects on the bottom of the comparatively large basin below the sprue and does not interfere with the test. This arrangement is well designed for the intended use. However, it could not be considered for a standard fluidity test because it does not appear practical for alloys with high melting points and is too complex for use as a quality-control test in the shop.

Some investigators of fluidity have poured metal directly into the sprue of the test mold. This practice does not seem to be desirable because the kinetic energy of the metal being poured is transmitted directly to that entering the flow channel. Moreover, it is apt to cause excessive and uncontrolled turbulence. If the test were to be reasonably reproducible under these conditions, metal would have to be poured from exactly the same height and at exactly the same rate, each time.

These variables are difficult to control and it is advisable to follow the methods employed by a number of the more recent investigators, namely, to design the test mold with a pouring basin which discharges into the sprue at a fixed height above the plane of the flow channel and which overflows into another basin at a small, fixed height above the plane of entry to the sprue.

Thus, if a high rate of pouring is employed so that the sprue fills quickly and remains filled, the pressure head is kept constant within the limits set by the difference between the two discharge levels. The shortest interval between discharge levels in any of the work reported is ¼ in., which is the distance employed by Andrew, Percival and Bottomley[87], and Taylor, Rominski and Briggs[89]. The latter test mold has been used widely enough to indicate that this dimension is ample although it obviously could not be much less than ¼ in.

If the amount of metal to be used for a fluidity test is to be kept reasonably small, the pouring basin can not be large. However, from the standpoint of dissipation of kinetic energy of the metal being poured, it is desirable to employ a fairly large basin. Moreover, it is essential that the pouring basin be larger than a certain minimum size so that temperature measurements can be taken therein. Size of the pouring basin is discussed further in the section on temperature measurement.

Skimmers. It is well known that the presence of slag and dross has a pronounced effect upon the apparent fluidity of a metal. The effect is more noticeable with some nonferrous alloys than with iron-base alloys. Accordingly, few of the investigators who have worked with irons and steels have given attention to skimming devices.

However, if the intention of specifying a standard fluidity test for all of the commonly cast metals is to be realized, it appears essential that some means be provided in the gating system to prevent floating, nonmetallic material from entering the flow channel.

Strainer Cores

A strainer core can be inserted in the sprue in the manner employed by Curry[22] and others. However, unless the openings through the core have a total cross-sectional area which is sufficient to allow rapid filling of the sprue, it is believed that some of the reproducibility of the test is lost. Since the core must have some strength and, therefore, be relatively large in comparison with the total area of the openings, the cross-sectional area of the sprue must be considerably larger above the core than below it.

Therefore, the sprue fills to a constant level less rapidly with a strainer core than without it, even though no constriction is caused by it. Moreover, the core acts to chill the metal somewhat, and it is desirable to keep

Fig. 7—Fluidity mold incorporating fusible stoppers in sprue (Courty).

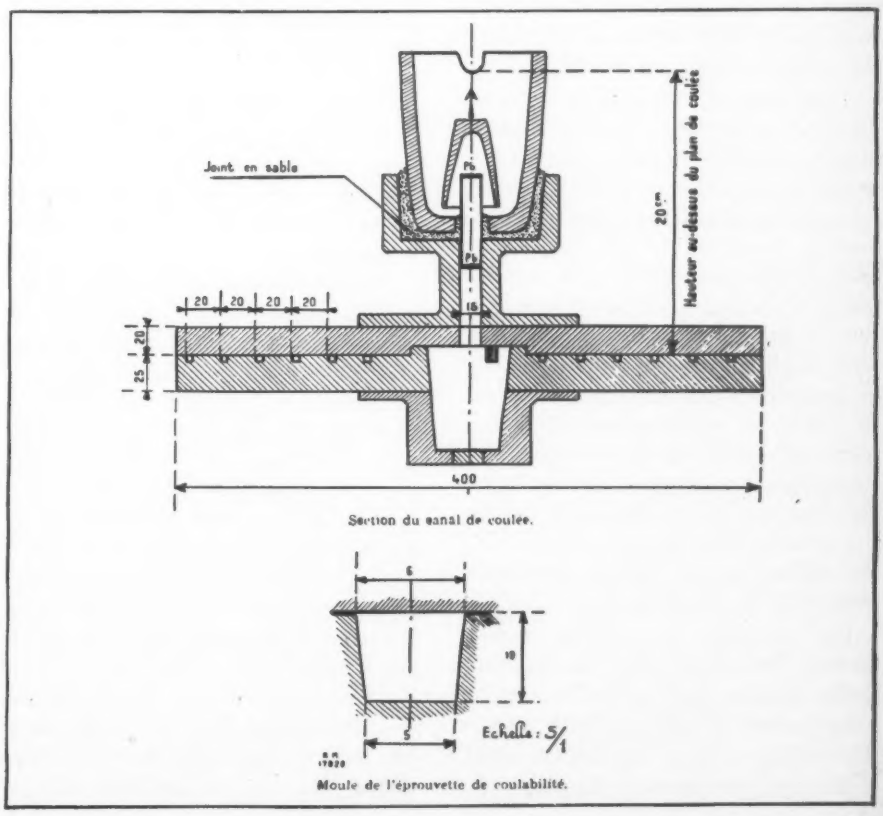


Fig. 8—Cast pair of spirals (Mott, Schaefer, and Cook).

the chilling action to a minimum.

Since it has been recommended that a pouring basin be made in the mold, a modification of the skimming device used by Mott, Schaefer and Cook[105] is believed to be satisfactory for skimming dross and slag from the metal. A photograph of a fluidity casting, taken from their report, is reproduced in Fig. 8. The suggested modification is that the section between the skimmer and the sprue be reduced to allow it to fill more completely before metal enters the sprue.

Temperature Measurement and Transfer of Metal to Test Mold. For fluidity testing in the laboratory, accurate measurement of the true temperature of the metal is an important part of the procedure because temperature has such a profound effect upon fluidity irrespective of other conditions which may alter it. Some of the inconsistencies in reported data probably are due to errors of temperature measurement. Even if the temperature of the metal is measured accurately in the furnace or in the ladle before the sample is poured into the mold, the metal can be chilled considerably as it is transferred.

For example, if metal is poured directly from a crucible or lip-pour ladle, the pouring lip may be at any temperature within a wide range depending upon a number of conditions; if the metal is dipped with a sampling spoon, the chilling effect of the spoon is dependent upon its mass, the degree of preheat, and the time required for the transfer. Thus, for laboratory tests, it is desirable to measure temperature of the metal in the fluidity mold itself.

Temperature Measurement Technique

Mott, Schaefer and Cook[105] have used a method which appears to be reliable. Their technique is to place the hot junction of a platinum, platinum-rhodium thermocouple in the pouring basin of the mold, Figs. 8 and 9, so that the temperature of the metal can be taken just before it enters the sprue. For this technique to be successful it is required that the couple respond rapidly and the indicator or recorder be equally responsive.

These investigators used a spot-welded couple with the junction no larger than the elements. This couple was pulled through a single-bore, fused-silica sheath with thin walls so that the thermal lag was not more than 4 or 5 sec. A rapidly responding indicator was used with the couple. It is necessary to have metal flowing into the pouring basin for a period which is long enough for the couple to respond to the true temperature of the metal before it enters the sprue.

This condition can be controlled by establishing suitable dimensions for the pouring basin and by regulating the rate of pouring with a pouring cup. Mott, Schaefer and Cook used a pouring basin which is roughly cubical in shape with the length of each edge being approximately 4½ in.

Temperature measurements are not required for quality-control tests of fluidity in the shop. It should be emphasized again that useful information can be gained from this type of fluidity testing only by correlation of test results with observations of fluid performance of the metal on the casting floor for each shop.

Therefore, the important thing to be observed in shop practice is that the metal is transferred to the test mold in exactly the same manner for each test. For example, the procedure at the U. S. Naval Research Laboratory for making fluidity tests of steel in the arc-furnace for control purposes is as follows:

1. The bath is rabbled just before a sample is taken.
2. A 10-lb. sampling spoon, initially dry and at room temperature, is slagged for a period of 10 sec. as the melter counts, "one-thousand and one, one-thousand and two etc."
3. A spoonful of metal is dipped from a fixed position with respect to the electrodes and is withdrawn quickly, but not hurriedly, from the furnace.
4. The metal is deoxidized with a strip of aluminum unless the final

Fig. 9—Mold and thermocouple assembly prepared for pouring (Mott, Schaefer, and Cook).

additions have been made to the furnace prior to time of the test.

5. The spoon is inverted just above the pouring cup which is centered over the pouring basin. The average deviation from the standard time-cycle for steps 3, 4, and 5 is approximately 3 sec.

Sampling from Bottom-Pour Ladles. When it is desirable to make fluidity tests from a bottom-pouring ladle, some provision must be made to deal with the extraordinary force of the metal as it comes from the nozzle.

Investigations

Kron and Lorig[79] developed a test mold with which they were able to pour fluidity tests from a bottom-pouring ladle containing 27 tons of steel (Fig. 10). The flow channel of this mold is a modification of that developed by Ruff. Only a few tests were made with the mold and the data are insufficient to support a recommendation for its adoption.

Taylor, Rominski and Briggs altered the pouring basin of their laboratory test mold and placed a baffle core between the pouring basin and the sprue so that samples of steel could be taken from a bottom-pouring ladle. Other details are the same as those of the test piece for laboratory work or tests on the melting floor where a sampling spoon is used to transfer the metal to the mold. A photograph of the pattern for this test mold is shown in Fig. 11. Satisfactory tests were obtained with the large test piece and it is believed to be generally acceptable for use with a bottom-pouring ladle.

Shop Tests vs. Laboratory Tests. The idea has been emphasized that one well designed test piece should be suitable for both shop tests and laboratory tests of fluidity. The flow channel, sprue, and pressure head of molten steel should be identical in all cases. However, for the pouring basin, two or possibly three designs are necessary because of the differences in requirements of pouring methods.

For laboratory tests, the pouring basin must be sufficiently large so that accurate temperature measurements can be made of the metal as it enters the mold. The pouring basin of a mold which is to receive metal from a bottom-pouring ladle should also be large. By contrast, a smaller pouring basin is required for shop tests if metal is to be removed from a furnace with a sampling spoon.

It is not suggested that shop tests can be made with the same control and care with which a laboratory test is conducted. However, it is believed that the results of fluidity testing obtained from molds having the same pressure head of molten metal, flow channel and sprue, although with pouring basins sufficiently different in design to satisfy the requirements stated, would be suffiicently comparable so that operating and laboratory personnel could exchange information and improve practice for the benefit of the industry.

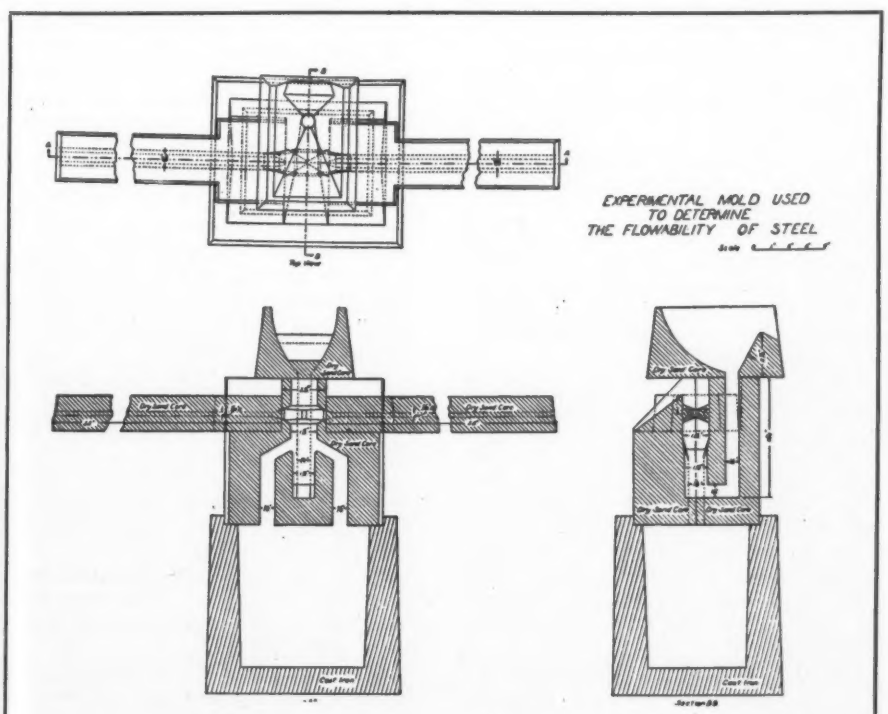


Fig. 10—Detail drawing of experimental mold used to determine the flowability of steel in foundry trials (Kron and Lorig).

Summary of Recommendations

A review of available information indicates that a standard fluidity test piece should have design details and provisions for operation similar to the following:

Flow Channel.

Half-circular or trapezoidal cross-section.

Cross-sectional area should be established at some value within the range of 1/12 to 1/7 sq. in.

Length of approximately 60 in.

Spiral configuration with a vent at the end.

Mold Material.

Green sand without a mold wash.

A.F.A. grain size of 80 ± 5.

Minimum A.F.A. permeability of 75.

Gating Arrangement.

Vertical sprue with a cross-sectional area approximately six times that of the flow channel.

Receiving well at the base of the sprue only slightly larger in diameter than the sprue.

Pressure Head.

Exact distance established within the range of 1 to 2 in. from plane of discharge from pouring basin to sprue.

Variation regulated to ¼ in. by discharge levels from pouring basin.

Pouring Basin.

At least two designs are necessary.

One should be sufficiently large to dissipate kinetic energy of metal being taken from a bottom-pouring ladle and to allow response of pyrometric equipment for temperature measurement in laboratory tests.

Other basin should be small enough so that the sample can be taken with a spoon.

Provided with an overflow to maintain a constant pressure head within the limits mentioned.

Skimmers.

Baffle core placed between pour-

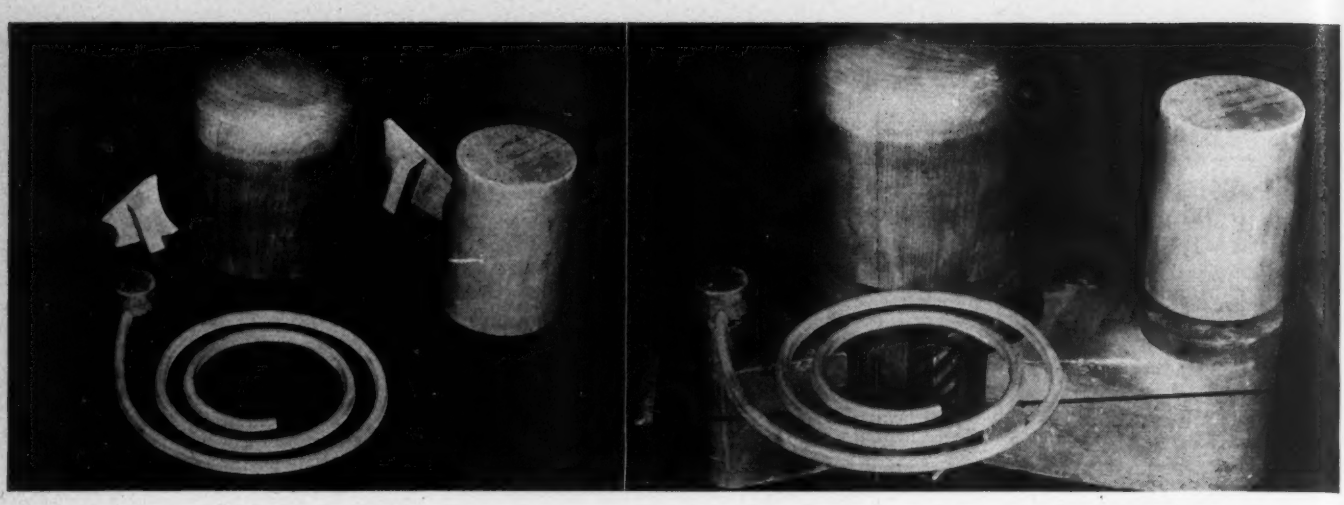


Fig. 11—Pattern for large fluidity test piece—(left) spaced properly for ramming in drag—(right) individual parts separated by glass plate (Taylor, Rominski, and Briggs).

ing basin and sprue to skim nonmetallic material from metal entering sprue.

Temperature Measurement for Laboratory Tests.

Lightly sheathed platinum, platinum-rhodium thermocouple inserted in pouring basin.

High-speed indicator or recorder used.

Fluidity Sampling from Bottom-Pour Ladles.

Mold designed so that all details except pouring basin are the same as the test mold for samples taken with spoons or from lip-pour ladles.

Acknowledgment

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Bibliography

Items 1 through 60 are taken from the *Bibliography on the Fluidity and Viscosity of Metals*, published by the Iron and Steel Institute, 28 Victoria Street, London, S. W. 1. 1936.

1. T. D. West, *Metallurgy of Cast Iron*, Cleveland (1902).

2. C. E. Fawsitt, "On the Determination of Viscosity at High Temperatures," Proceedings of the Royal Society, vol. 80, p. 290 (1908).

3. C. E. Fawsitt, "Viscosity Determinations at High Temperatures," *Journal*, the Chemical Society, vol. 93, Part 2, pp. 1299-1307 (1908).

4. R. Arpi, "Viscosity and Density of Fused Metals," *International Journal of Metallography*, vol. 5, p. 142 (1914).

5. M. Pluss, "Viscosity and Density of Liquid Metals and Alloys," *Zeitschrift fur anorganische Chemie*, vol. 93, p. 1 (1915).

6. R. Moldenke, *The Principles of Iron Founding*, New York (1917).

7. R. Middell, "The Fluidity of Molten Cast Iron," *Proceedings*, British Foundrymen's Association, pp. 44-55 (1917-1918).

8. D. Saito and K. Hayashi, "Investigation of the Fluidity of Metals and Their Alloys," Memoirs of the College of Engineering, Kyoto Imperial University, vol. 2, pp. 83-100 (1919), vol. 4, pp. 165-178 (1924).

9. C. H. Desch, "The Fluidity of Molten Metals," *Proceedings*, Institute of British Foundrymen, vol. 15, pp. 489-516 (1921-1922).

10. "The Degree of Fluidity of Molten Metals," *Giesserei-Zeitung*, vol. 19, pp. 645-648 (1922).

11. F. Sauerwald, "On the Internal Friction of Molten Metals and Alloys. I.—The Measuring Process and the Internal Friction of Lead-Bismuth Alloys," *Zeitschrift fur anorganische Chemie*, vol. 135, pp. 255-264 (1924).

12. K. Hayashi, "On the Fluidity of Molten Metals," *Tetsu-to-Hagane*, vol. 10, pp. 159-166 (1924).

13. C. Cury, "Testing Cast Iron for Life," Association Technique de Fonderie, Nov. 6, 1924; *Foundry Trade Journal*, vol. 31, Jan. 15, pp. 52-55 (1925).

14. P. Oberhoffer and A. Wimmer, "The Influence of Temperature and Chemical Composition on the Viscosity of Iron," *Stahl und Eisen*, vol. 45, pp. 969-977 (1925).

15. C. B. Bellis, "A Viscosimeter for Use at High Temperatures," *Chemical and Metallurgical Engineering*, vol. 32, p. 645 (1925).

16. "Viscosimeter," *Chemical and Metallurgical Engineering*, vol. 32, pp. 885-886 (1925).

17. F. Sauerwald, "The Scientific Conception of Some of the Important Properties of Metals for Casting and Hot-Working," *Zeitschrift fur Metallkunde*, vol. 18, May, pp. 137-142; June, pp. 193-195 (1926).

18. F. Sauerwald and K. Topler, "On the Internal Friction of Molten Metals and Alloys. II.—Further Information on the Methods of Measuring and on the Internal Friction of Bi-Sn Alloys and the Alloy Cu Sn," *Zeitschrift fur anorganische Chemie*, vol. 157, pp. 117-137 (1926).

19. L. Guillet and A. Portevin, "Influence of Chemical Composition of Alloys on the Facility of Obtaining Moulded Pieces," *Comptes Rendus*, vol. 183, pp. 634-636 (1926).

20. L. Losana, "The Fluidity of Metals and Alloys in the Liquid State," *Il Noliziario Chimico-Industriale*, vol. 2, pp. 1-4, 63-66, 121-125 (1927).

21. F. Sauerwald and A. Bieneas, "On the Viscosity of Molten Metals and Alloys. III.—The Viscosity of Copper, Antimony and Lead, and of the Alloys Copper-Antimony, Copper-Tin, Lead-Bismuth," *Zeitschrift fur anorganische Chemie*, vol. 161, p. 51 (1927).

22. C. Curry, "Test Bars to Establish the Fluidity Qualities of Cast Iron," Transactions, American Foundrymen's Association, vol. 35, pp. 289-306 (1927).

23. H. Thielmann and A. Wimmer, "The Internal Friction of Liquid Pig Iron," *Stahl und Eisen*, vol. 47, March 10, pp. 389-399 (1927).

24. G. M. Enos, "The Flow of Metals in Moulds," *Metals and Alloys*, vol. 1, Feb., pp. 362-364; March, pp. 417-419 (1930).

25. E. K. Widen and N. G. Girschowitsch, "On the Fluidity of Low-Silicon White Iron," *Giesserei*, vol. 17, Nov. 21, pp. 1120-1135 (1930).

26. T. F. Jennings, "Chromium in Cast Iron Mixtures," Transactions, American Foundrymen's Association, vol. 38, p. 806 (1930).

27. "The Life of Malleable Cast Iron," *Foundry Trade Journal*, vol. 44, May 28, p. 374 (1931).

28. C. M. Saeger and A. I. Krynitsky, "A Practical Method for Studying the Running Quality of a Metal Cast in Foundry Molds," Transactions, Amer-

ican Foundrymen's Association, vol. 39, pp. 513-540 (1931).

29. A. Courty, "Contribution to the Study of Castability," *Revue de Metallurgie, Memoires,* vol. 28, March, pp. 169-182; April, pp. 194-208 (1931).

30. "The Casting Properties of Metals," *Metallurgist,* vol. 7, pp. 109-110, 122-123 (1931).

31. E. Scheuer, "Comparative Fluidity Tests," *Metallwirtschaft,* vol. 10, pp. 884-885 (1931).

32. C. H. Weiss and P. Woog, "The Unification of the Term Viscosity," New International Association for Testing Materials, Zurich, 1931.

33. R. Berger, "Measuring the Running Quality of Molten Metals and Its Application to the Study of Iron-Carbon Alloys," *Bulletin,* Official du Syndicat General des Fondeurs de Belgique et de l'Association Technique de Fonderie de Belgique, no. 17, Aug., 1932; *Metals and Alloys,* vol. 4, p. 176 (1933).

34. L. Losana, "Fluidty and Castability of Ultra-Light Alloys," *Alluminio,* vol. 1, pp. 237-243 (1932).

35. A. Portevin and P. Bastien, "The Principal Factors in the Castability of Pure Metals," *Comptes Rendus,* vol. 194, pp. 599-601 (1932).

36. A. Portevin and P. Bastien, "The Castability of Alloys," *Comptes Rendus,* vol. 194, pp. 850-853 (1932).

37. N. B. Pilling and T. E. Kihlgren, "Casting Properties of Nickel Bronzes," TRANSACTIONS, American Foundrymen's Association, vol. 40, pp. 289-309 (1932).

38. T. Matsukawa and D. Saito, "Measurement of Viscosity of Molten Light Alloys, and Cast Irons at High Temperatures by the Rotating Cylinder Method," *Memoirs,* College of Engineering, Kyoto, vol. 7, pp. 49-114 (1932).

39. Kirstenpfad, "Flow Phenomena in Foundry Moulds and Their Influence on the Duration of Casting," *Zeitschrift des Vereines deutcher Ingenieure,* vol. 77, Nov. 11, pp. 1221-1222 (1933).

40. P. Bastien, "Contribution to the Study of the Casting Properties of Metals and Alloys," *Publications scientifiques et techniques du Ministere de l'Air,* no. 20, pp. 95-143 (1933).

41. A. Portevin and P. Bastien, "Contribution to the Study of the Castability of Ternary Alloys," *Comptes rendus,* vol. 196, pp. 1396-1398 (1933).

42. A. Portevin and P. Bastien, "Castability and Contraction of Magnesium and Its Alloys with Aluminum and Copper," International Foundry Congress, Prague, 1933.

43. C. M. Saeger and E. J. Ash, "Properties of Gray Cast Iron as Affected by Casting Conditions," TRANSACTIONS, American Foundrymen's Association, vol. 41, pp. 449-468 (1933).

44. F. H. Stott, "The Measurement of the Viscosity of a Molten Metal by Means of an Oscillating Disc," *Proceedings,* Physical Society, vol. 45, pp. 530-544 (1933).

45. H. Thyssen, "The Influence of Silicon and Aluminum on the Resistance of Cast Iron to High Temperatures," *Journal,* Iron and Steel Institute, no. II, pp. 153-218 (1934).

46. Thyssen and Perin, "Contribution to the Study of the Fluidity of Cast Iron," American Foundrymen's Association, Oct., 1934, Preprint No. 23.

47. A. I. Krynitsky and C. M. Saeger, "Effect of Melting Conditions on the Running Quality of Aluminum Cast in Sand Moulds," *Journal of Research,* National Bureau of Standards, vol. 13, Oct., pp. 579-588 (1934).

48. H. Esser, F. Greis and W. Bungardt, "Viscosity of Liquid Pig Iron," *Archiv fur das Eisehuttenwesen,* vol. 7, Jan., pp. 385-388 (1934).

49. A. Portevin and P. Bastien, "Castability of Ternary Alloys," *Journal,* Institute of Metals, no. 1, pp. 45-58 (1934).

50. A. Rademacher and F. Sauerwald, "On the Measurement of the Viscosity of Metals," *Mitteilungen aus den Forschungsanstalten der Cutehoff mungshutte,* vol. 3, pp. 124-140 (1934).

51. A. von Zeerleder and R. Irmann, "A Contribution to the Determination of the Castability of Aluminum Alloys," *Zeitschrift fur Metallkunde,* vol. 26, pp. 271-274 (1934).

52. V. J. Fundator, "Influence of Dust Films on the Fluidity of Molten Cast Iron and Duralumin," *Niimash Izvestia Nauchno-issledovatelskogo Instituta Maschinostroenia i Metalloobrabotki,* no. 8, pp. 66-70 (1934) (In Russian).

53. R. Berger, "Contribution to the Study of the Castability of Cast Irons," *Revue de Metallurgie, Memoires,* vol. 31, pp. 337-380, Sept., 1934.

54. J. T. Mackenzie, "Difficult Tests for Founding Properties," *Metal Progress,* vol. 27, p. 56, March, 1935.

55. "Fluidity Tests on Metals," *Metal Industry* (London), vol. 46, p. 204, Feb. 15, 1935.

56. E. Touceda, "Fluidity Test Equipment for White Iron," *Metals and Alloys,* vol. 6, p. 130, May, 1935.

57. H. Obermuller, "The Casting Properties, Mould Capacity, and Fluidity of Cast Metals and Alloys," *Giesserie-Praxis,* vol. 56, p. 413 (1935).

58. J. H. Andrew, "Suggestions for Research on Steel Castings," Institute of British Foundrymen, July 2-5, 1935; *Foundry Trade Journal,* vol. 53, p. 49, July 18, 1935.

59. H. Remy, "An Attempt to Standardize the Life Test," International Foundry Congress: *Foundry Trade Journal,* vol. 53 p. 231, Sept. 26, 1935.

60. A. von Zeerleder, "The Castability of Aluminum," *Metal Industry* (Lond.), vol. 47, pp. 531-534, 540, Nov. 29, 1935.

61. H. V. White and F. O. Reese, "The Effect of Zinc and Sodium on the Relative Runnability of Type-Metal Alloys," *Bulletin,* Virginia Polytechnic Institute, Sept. 1935, vol. 28, no. 11, Engineering Experiment Station Series, Bulletin 21.

62. Takuity Morinaga, "The Fluidity of Aluminum Casting Alloys," Tetsu to Hagane (*Journal,* Iron and Steel Institute, Japan), vol. 22, no. 1, pp. 41-44 (1936).

63. C. F. Joseph, "Measuring and Controlling Pouring Temperatures and Fluidity," TRANSACTIONS, American Foundrymen's Association, vol. 44, pp. 103-132 (1936).

64. P. G. Petrov, "Influence of Chemical Composition and Casting Temperature on Casting Properties of Iron," *Liteinoe Delo,* vol. 7, no. 6, pp. 4-15 (1936).

65. W. Ruff, "The Running Quality of Liquid Malleable Iron and Steel," Iron and Steel Institute, *Carnegie Scholarship Memoirs,* vol. 25, pp. 1-39 (1936).

66. R. H. Greaves, "Fluidity of Steel in Relation to Method of Manufacture, Composition, and Temperature of Casting," Iron and Steel Institute, *Special Report No. 15,* pp. 26-42 (1936).

67. J. H. Andrew, R. T. Percival and G. T. C. Bottomley, "The Fluidity of Iron—Carbon and Other Iron Alloys," Iron and Steel Institute, *Special Report No. 15,* pp. 43-64 (1936).

68. H. C. Hall, "Structure and Characteristics of Aluminum Alloys," *Proceedings,* Institute of British Foundrymen, vol. 30, pp. 283-321 (1936-1937).

69. J. W. Bolton, *Gray Cast Iron,* pp. 149, 267-270. Penton Publishing Co., Cleveland (1937).

70. P. Berg and N. Dmitriev, "Castability of Cast Iron." *Liteinoe Delo,* vol. 8, no. 3, pp. 28-32 (1937).

71. P. Bastien, "Viscosity, Surface Tension, and Castability in Metallurgy and, more particularly, in Founding," *Bulletin,* de l'Association Technique de Fonderie, Sept. 1937.

72. J. H. Pearce, "This Fluidity," *Foundry Trade Journal,* vol. 58, p. 7 (1938).

73. K. Schiffer and W. Feldmann, "Pig Iron for Steelmaking and Its Relation to the Melting Process in the Steelworks," *Stahl und Eisen,* vol. 58, pp. 641-646, June 16, 1938.

74. E. Lips and H. Nipper, "Investigation of the Effect of Crystal Precipitation on the Flow-Properties of Melts," *Giesserei,* vol. 25, pp. 369-372, July 29, 1938.

75. J. H. Andrew, G. T. C. Bottomley, W. R. Maddocks, and R. T. Percival, "The Fluidity of Alloy Steels," Iron and Steel Institute, *Special Report No. 23,* pp. 5-32 (1938).

76. R. H. Greaves, "Introductory Comments on the Ruff Test," Iron and Steel Institute, *Special Report No. 23,* pp. 33-34 (1938).

77. T. R. Walker, "Works Results Using the Ruff Fluidity Test," Iron and Steel Institute, *Special Report No. 23,* pp. 35-43 (1938).

78. R. J. Sarjant and T. H. Middleham, "Fluidity-Temperature Relations of Cast Steels of Various Compositions," Iron and Steel Institute, *Special Report No. 23,* pp. 45-60 (1938).

79. E. C. Kron and C. H. Lorig, "The Flowability of Cast Steel," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 583-608 (1939).

80. H. B. Gardner and C. M. Saeger, "The Effect of Aluminum and of Antimony on Certain Properties of Cast Red Brass," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 423-449 (1939).

81. L. W. Eastwood and L. W. Kempf, "The Measurement of Fluidity of Alumi-

num Casting Alloys," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 571-582 (1939).

82. E. J. Ash, "Malleable Iron Castability Tests," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 609-619 (1939).

83. N. A. Zeigler and H. W. Northrup, "Effect of Superheating on Castability and Physical Properties of Cast Iron," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 620-652 (1939).

84. G. Delbart, "Cast Steel and Forged Steel," *Bulletin,* de l'Association Technique de Fonderie, vol. 13, pp. 156-171, May, 1939.

85. F. Eisermann, "The Fluidity of Steels in the Light of Recent Investigations," *Stahl und Eisen,* vol. 59, pp. 857-861, July 27, 1939.

86. C. W. Briggs, "Fluidity of Metals," *Metals Handbook,* American Society for Metals, Cleveland, pp. 98-103, 1939 Ed.

87. R. J. Wilcox, "Castability of Alloy Steel Castings," *Foundry,* vol. 67, pp. 28-29, Dec., 1939.

88. A. B. Kinzel and R. Franks, *The Alloys of Iron and Chromium, Volume II—High-Chromium Alloys,* p. 257. Published for the Engineering Foundation by the McGraw-Hill Book Company, New York (1940).

89. H. F. Taylor, E. A. Rominski and C. W. Briggs, "Fluidity of Ingot Iron and Carbon and Alloy Cast Steels," TRANSACTIONS, American Foundrymen's Association, vol. 49, pp. 1-93 (1941).

90. W. Linicus, "Choice of Materials and Questions of Casting Technique in Making Aluminum Castings," *Giesserei,* vol. 28, pp. 413-419, 434-437 (1941).

91. H. F. Taylor and E. A. Rominski, "Fluidity of Cast Steel," *Iron Age,* vol. 148, pp. 40-44, Nov. 27, 1941.

92. H. F. Taylor and E. A. Rominski, "Measuring the Fluidity of Cast Steel," AMERICAN FOUNDRYMAN, vol. 4, no. 1, pp. 10-14; no. 2, pp. 12-13 (1942).

93. H. F. Taylor and E. A. Rominski, "Fluidity of Cast Steel. Spiral Test Molds for Fluidity Measurements," *Foundry Trade Journal,* vol. 66, pp. 137-138 (1942).

94. F. G. Sefing, "Molten Metal Conditions Affect Casting Quality," *Foundry,* vol. 70, pp. 78-79, July, 1942.

95. P. Bastien, "Casting Characteristics of Metals and Alloys," *Revue Metallurgie,* vol. 40, pp. 353-367, Dec., 1943.

96. G. Burgess, "Factors Influencing the Fluidity of Cast Iron," *Foundry Trade Journal,* vol. 69, pp. 197-204, March 11, 1945.

97. *Vanadium Steels and Irons,* p. 162. Vanadium Corporation of America, New York (1945).

98. W. Ruff, "New Results of Casting Tests for Melts of Chrom-Molybdenum-Steels with and without Nickel in Basic Electric Arc Furnace and Siemens-Martin Furnace," *Stahl und Eisen,* vol. 63, pp. 438-443, June 3, 1943.

99. W. Bonsack, "The Effects of Alloying Elements on Aluminum Casting Alloys," TRANSACTIONS, American Foundrymen's Association, vol. 52, pp. 789-813 (1944).

100. *Alloy Cast Irons Handbook,* Alloy Cast Irons Committee, Gray Iron Division, pp. 7, 11, 16 and 34. American Foundrymen's Association, Chicago (1944).

101. H. T. Protheroe, "The Influence of Melting Conditions on the Physical Properties of Steel Castings," Iron and Steel Institute Advance Copy, August, 1944.

102. J. L. Erickson, "Little-Recognized Factors Influencing the Quality of Aluminum Pressure Die Cast Parts," *Aluminum and Magnesium,* vol. 1, no. 8, pp. 16-19 (1945).

103. W. W. Moss, Jr., "Fluosilicates and Compounded Inhibitors in Magnesium Casting II," *Light Metal Age,* vol. 3, no. 8, pp. 21-28 (1945).

104. L. A. Carapella and W. E. Shaw, "Fluid Performance of Magnesium," *Light Metal Age,* vol. 3, no. 11, pp. 35-36 (1945).

105. W. S. Mott, R. H. Schaefer and E. Cook, "Experimental Production of Pilot Static and Centrifugal Castings for the Armed Services: Part III—The Fluidity of Cast Alloyed Steels and Irons," NDRC Division 18, OSRD No. 5634.

CHAIRMAN CONFERENCE

Program Stresses Chapter Cooperation

SERVING A.F.A. MEMBERS BEST through chapter programs will be the theme of the third Annual Chapter Chairman Conference, Wednesday and Thursday, July 24-25, at the Stevens Hotel, Chicago. A program for national coordination of chapter activities, prepared by the National Office at the request of the chapters, will be presented to the delegates in outline form; and ensuing discussions will center on its development.

Among important points discussed will be: how the National Office can assist chapter program chairmen; regional meetings and their possibilities; advantages of preparing chapter programs a year in advance; functions of program committees; and the question of speaker expenses and accommodations.

National Officers to Attend

Designed to materially increase the strength and prestige of the chapters, as well as to demonstrate the role of A.F.A. as the national technical society of the foundry industry, the program to be offered is concise, limited in scope, and within the ability of every chapter to carry out.

On hand to greet the chapter Chairmen will be A.F.A. National President Fred J. Walls; National Vice-President Sheldon V. Woods; and National Director Max Kuniansky, Chairman of the Conference, as well as several other National Directors, and members of the National Office staff.

President Walls will deliver the address of welcome to the chapter Chairmen on Wednesday morning, prior to opening of discussions.

Schedule for the conference includes sessions through which delegates will acquire familiarity with all phases of A.F.A. National activities and understanding of the many ways in which the National Office offers assistance to chapter officers and committees.

Accommodations Arranged

Room reservations will be made in advance for all who request accommodations at the Stevens Hotel, by the National Office, which will register in all official delegates. Those arriving prior to 8:00 am, July 24, need only inquire at the hotel desk for information as to rooms assigned. Arrivals after 8:00 am should go directly to the upper tower, 31st floor, where room keys will be distributed and identification badges given out before the Conference gets under way.

Members of the National Office Staff, including W. W. Maloney, Secretary, and F. E. Wartgow, will register in at the Stevens Hotel Tuesday afternoon, July 23, and will be available thereafter to assist delegates in every way possible.

Ontario Foundry Burns

SWEEPING THROUGH the entire plant at Preston, Ont., fire of undetermined origin destroyed the gray iron foundry of Clare Bros. & Co. Ltd., with loss estimated in the neighborhood of $200,000. Workmen are reported searching ruins for patterns and tools which can be salvaged; and officials of the firm, which produces components of heating equipment, indicate that construction of a new plant on or adjacent to the site is planned

CUPOLA REFRACTORIES

LINING AND PATCHING

E. J. Lally
Forest City Foundries Co.
Cleveland

IT IS A KNOWN FACT that the cupola is the heart of the foundry; therefore, for good operation it is essential to use the best refractories available with the most advanced practices of lining and patching.

The shell of the cupola should conform to a perfect circle as nearly as possible. Any irregularities allow excessive expansion and contraction between the joints of the lining bricks.

In lining the well of the cupola, any of several methods may be used. Selection of a method depends upon the size of the shell and the well diameter desired. One method is placing of the 2- or 2½-in. brick next to the shell and cupola block in front, the cupola block being exposed to the metal. In another method the cupola block is placed next to the shell and the 2- or 2½-in. brick exposed to the metal.

This latter method offers the advantage of allowing replacement of the straights with but little effort. Another method utilizes 4-in. circle blocks next to the shell and faced off with cupola blocks. Still another is in the use of two cupola blocks, one in front of the other. In still another method, 2- or 2½-in. straights alone are used, depending upon the well diameter desired. The final method, say in a No. 3 cupola, is the use of a cupola block alone in the well.

All of the foregoing methods require the use of a soft, well-mixed mud between the joints of the bricks, the bricks themselves being dipped in a "clay soup." In all of the methods mentioned, "soup" is poured freely between the shell of the cupola and the bricks next to the shell to fill any voids.

It should be mentioned at this point that in lining the cupola well, the joints of the bricks of the course next to the shell and the joints of the face brick should be staggered. This helps to eliminate any possibility of molten metal seeping through the bricks to the shell. After the well has been completely lined, the face brick are coated thoroughly with a commercial refractory wash.

Having lined the cupola well, the next step is to properly fit the tuyeres in place. In the case of the individual tuyeres, it is a good policy, if possible, to bolt the tuyeres to the shell. Caution should be used to insure that a solid, tight fit is obtained between each tuyere, especially if the tuyeres are not bolted to the shell.

In the case of the continuous tuyere, it is important that the shell at this point conforms to as perfect a circle as possible. This is to insure a close fit so that no air is lost in passing from the windbox through the tuyeres.

The type of lining used between the tuyeres and to a point 2½ ft. below the charging floor depends upon the size of the shell and the diameter that is desired.

It has been advantageous in the lining of a cupola to have a ring bolted to the shell about 2 ft. above the melting zone, so that when only the melting zone is relined the brick above the ring is held in place. The number of rings in the stack of a cupola depends upon the height of the stack.

The three courses of brick immediately above the tuyeres are placed so as to form an overhang of 2 to 3 in. over the tuyeres. This aids in preventing the tuyere plates from being burned off by the molten metal as it passes by the tuyeres, and also helps to keep the metal from dripping into the tuyeres. This overhang can be obtained by an extra 2- or 2½-in. straight being placed in the three courses.

The section between the overhang and a point 2½ ft. below the charging floor is lined according to the diameter desired.

In one lining method, a 2-in. straight is placed next to the shell and a cupola block in front of the 2-in. straight. Another method utilizes two cupola blocks next to each other to form a course. If the cupola is small, the stack short, and only small tonnages melted, a single cupola block next to the shell is sufficient lining. Here again, the bricks

Proper selection of methods and materials for cupola lining and patching has much to do with the efficiency of the foundry melting. Good materials properly applied are important factors in cupola melting practice.

Presented at a Refractories Session of the Fiftieth Annual Meeting, American Foundrymen's Association, at Cleveland, May 7, 1946.

are dipped in a "soup" and the joints are sealed with a well-mixed clay. Any void between the back lining and the shell is eliminated by pouring "soup" between the shell and the back lining.

Again it is important when lining the stack to stagger the face block in regard to the back lining to prevent the joints from coinciding. This practice is continued up to 2½ ft. from the charging floor.

From 2½ ft. below the charging floor to 2 ft. above the charging floor a refractory block is used as a back lining. The face block is an iron brick. Here the iron brick is used as a face block to withstand the punishment received when the charges are thrown into the cupola.

These iron brick usually are hollow, so that "soup" can be poured into them to allow for contraction and expansion. The last row of iron brick above the charging floor usually is bolted into place. The course of bolted iron brick acts as a support for the arch brick used in the top part of the stack. The arch brick between the iron brick and the top of the stack seldom has to be replaced because it serves only to protect the shell from the flame of the cupola and has no other function.

After the cupola has been completely lined, a coke fire should be placed in it and allowed to burn for 24 hr. This will insure a completely dried cupola.

Patching A Cupola

The amount of work necessary to patch a cupola depends upon the amount of burn-out, which in turn depends upon the type of operation. If the cupola is charged unevenly, air distribution poor, melting rate high for the cupola size, or if the patching has been done sloppily, the amount of burn-out is affected accordingly. Therefore, in cases of consistenly uneven burn-out it is the responsibility of the melter to find out which of the foregoing factors causes the trouble.

After the drop has been cleaned up, the inside of the cupola should be sprayed thoroughly with water. A much cleaner job of chipping is obtained by wetting the inside of the cupola.

Once the cupola has been chipped, the first thing to consider is repair of the well. If the method of placing the cupola block next to the shell and the 2- or 2½-in. straight next to the metal is used, it must be made certain that the 2- or 2½-in. brick are in good shape. If not, they must be replaced.

If the cupola block is exposed to the metal and the well is in need of repair, a rammed mix that is fairly dry should be rammed into the eroded area, preferably with an air hammer. After the well has been repaired it should be washed with a clay soup or a refractory wash.

Materials Used

A number of different refractory materials are used for cupola patching. Some foundries use sandstone cut with the grain; others use sandstone cut against the grain, Newcastle firestone, fire brick, and some use their own recipe for a rammed mix. Any of these materials may be used as long as it gives good results.

It is important to note here that no matter what type of stone is used for patching, it should be dried so that all moisture is driven out. This will prevent "popping" of the patching material when bed is burned in.

After the melting zone of the cupola has been chipped *clean* and the well has been repaired, the next step in patching is to form a ring immediately over the tuyeres to act as a ledge or support for the remainder of the patchwork. This ring consists of small pieces of stone and well-mixed mud.

The type of mud used for patching varies with every foundry. Some of the mixes used are fire clay and new molding sand, fire clay and silica sand, silica sand and gannister, and fire clay alone. It is important to remember that no matter what mixture is used for patching, it should be mixed 18 to 24 hr. ahead of time.

Once the ring over the tuyeres has been made, the melting zone can be patched. If an excessive burn-out occurs in one area, it is better to tear out the lining to the shell and put in a new lining in that area. It is much more practical to do this than to try and patch over the area with patching material.

The ability of a patcher to work the patching stone into the variously burned areas is of great help in maintaining the original diameter of the cupola. It is up to the patcher to place a good layer of clay on the lining to hold the patching stone in place. Any areas that are burned deeper than others have to be patched with a thicker piece or pieces of stone so that no depressions are left in the patching.

If a certain area has only a slight burn-out, it is well to patch with a thin piece of stone so that the original diameter is not reduced. Finally, in an area that has had practically no burn-out it is wise to merely wash over it with a clay soup and leave it alone, because sooner or later it will burn off.

The writer would like to mention that any voids formed by the joints of the patching stones must be filled in with small pieces of stone. This helps to keep the larger stones in place and prevents them from slipping.

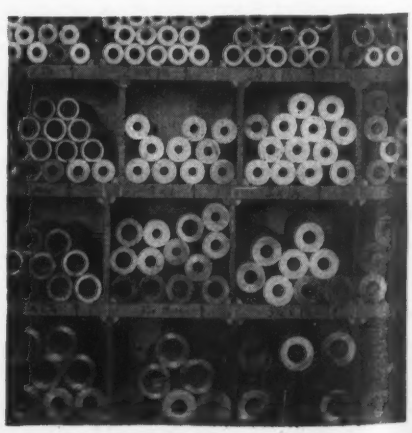
After the work of patching the cupola has been done, the patched areas should be washed with a thick clay soup.

In conclusion, if two cupolas are available and they are run alternately, it is preferable to dry the patching for at least 2 hr. by means of air and gas torches or a wood fire.

Aluminum Bronze Stock

CASTING TECHNOLOGY has developed a light, long-wearing product in centrifugally cast aluminum bronze bushing stock, according to announcement by Torrance Brass Foundry, Torrance, Calif.

The product, developed before the war and used extensively during hostilities by government contractors in the aircraft, automotive and maritime industries, is now available nationally through jobbing outlets for the first time.



Right—"Standard Bronze" centrifugally cast bushing stock.

CAST STEELS

LOW TEMPERATURE PROPERTIES

C. E. Sims
and
F. W. Boulger
Battelle Memorial Institute
Columbus, Ohio

A SERIES OF COMMERCIAL and experimental steels was studied to determine what correlations exist between the notched-bar properties and other factors such as composition, deoxidation practice, heat treatment, and microstructure in an attempt to learn more about the component factors of notched-bar properties of cast steels.

Melting and Foundry Practice. The steels tested in this investigation comprised two groups whose compositions are given in Tables 1 and 2. The 11 manganese-molybdenum steels were made commercially in open hearth or electric furnaces and received different deoxidation additions but were otherwise similar in composition. The test samples were cast in double-keel test blocks having two coupons 1⅛ in. square and 14 in. long. The coupons were burned from the raw castings with an oxyacetylene torch.

The other 18 steels were made in a laboratory induction furnace and cast in plate molds using a blind riser and atmospheric pressure for feeding. Figure 1 shows the test casting used for these steels.

Sixteen of the laboratory heats were melted in a magnesia crucible from a charge of ingot iron and ferrosilicon sufficient to give 0.10 per cent at melt down. After a temperature of 3000° F. was reached, the ferro-alloy additions were made, and the heat was held 2 min.

The final deoxidizer was then added, and the metal was poured into a small ladle. The time between deoxidation and casting was about one min., and the pouring temperature averaged 2965° F. as indicated by an optical pyrometer. The steel was cast in oil-sand molds which had been skin dried with a gas flame.

Two steels (Nos. 1 and 12, Table 2) exhibited central gas porosity when made by the procedure described in the foregoing. The defects were round, shiny holes and bore no similarity to shrinkage cavities except for their location. The typical appearance and the unsoundness in the silicon-killed steels with 0.63 per cent manganese is shown by the photograph in Fig. 2 at ¾X.

This type of porosity was found in castings made in skin-dried oil-sand molds and in molds dried for 6 hr. at 450° F. Five of the six test castings made from these compositions in oil-sand molds exhibited the center-line defects. The good casting was one of three made with a carbon boil during melting and oil-sand molds baked at 450° F. Six castings made later in fire clay-bonded molds dried at 450° F. for 4 hr. were sound. The composition of the mold mixtures is indicated in Table 3.

Porosity obtained in these castings was first attributed to hydrogen in the charge, but this theory was discarded when the carbon boil effected no improvement. The fact that the change to fire clay-bonded molds eliminated the trouble indicated that the core oil was the source of the trouble.

It seems likely that the core-oil residue, remaining after drying, reacted with the steel to form carbon monoxide, carbon dioxide, and hydrogen. Presumably some of the gas dissolved in the steel and later formed bubbles near the center where it was concentrated by dendritic segregation.

Similar steels deoxidized with aluminum (Nos. 2 and 13) and casting No. 3 with 1.55 per cent manganese were sound when cast under conditions giving porosity in the steels discussed in the foregoing. Apparently the presence of strong deoxidizers or the extra manganese was sufficient to prevent gassing in these castings.

Heat Treatment. The manganese-molybdenum steels were heat treated

Twenty-eight cast steels were tested to determine their notched-bar behavior at temperatures between 80 and −100° F. The data indicated that the notched-bar properties characteristic of a heat of steel were not reflected consistently by any other property measured. Therefore, it appears necessary to test each lot of steel when low-temperature properties are considered important, because little reliance can be placed on generalities correlating them with other characteristics of materials.

Presented at a Steel Session of the Fiftieth Annual Meeting, American Foundrymen's Association, at Cleveland, May 10, 1946.

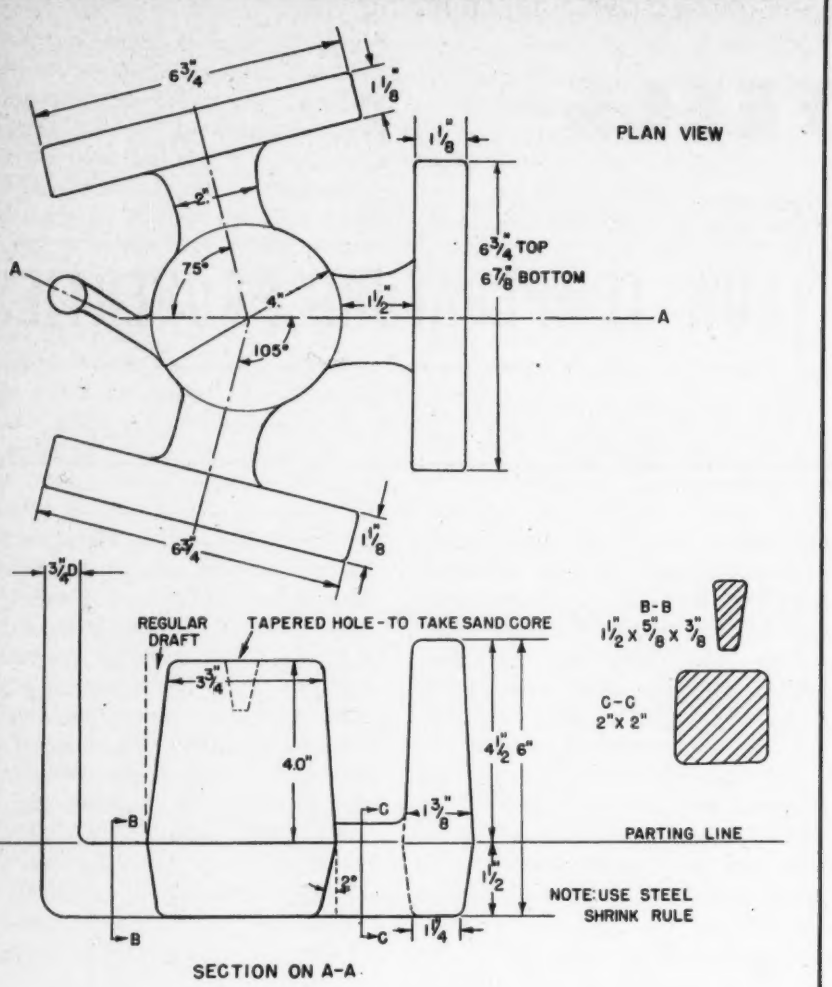


Fig. 1—Sketch of pattern for cast steel test plates.

in sections 1⅛ in. square and 14 in. long. The steels made in the laboratory were heat treated as plates 1⅛x6x6½ in. All raw castings were heated 2 hr. at 1800° F. and air cooled before receiving the final heat treatments. The manganese-molybdenum steels were water quenched from 1600° F., tempered 5 hr. at 1240° F., and air cooled.

Previous experiments had shown that this grade of steel was not temper brittle. The laboratory steels were tested in both normalized and drawn and water-quenched and tempered conditions. The heat-treating temperatures varied somewhat because of the differences in composition.

Grain Size and Hardenability. The austenite grain size developed by the actual heat-treating schedule was determined for all steels by means of an interrupted quench. The austenite grain-growth characteristics of the steels were evaluated in a qualitative way by carburizing samples for 8 hr. at 1750° F.

This temperature was about 150° F. higher than the actual heat-treating temperature and caused grain growth in some steels which were fine grained at the lower temperature. These tests showed that the experimental steels varied in their grain size and grain-growth characteristics with the deoxidation practice.

Standard end-quench hardenability tests were run on the laboratory steels using the same temperature and schedule employed in the actual heat treatment. The end-quench data indicated that steels Nos. 3 and 11 had the highest hardenability and were fully hardenable under the conditions employed. These two materials were silicon-killed medium-manganese steels.

Since no stock was available for end-quench tests on the manganese-molybdenum steels, their approximate hardenabilities were calculated according to Grossmann's method.[1] The hardenability data obtained by experiment and calculation are given in Table 4.

Metallography. Metallographic examinations were made on unetched samples of the various steels to determine the effect of differences in deoxidation practice on the inclusions. The distributions of the sulphides, which were the most numerous and probably the most important inclusions, were classified according to the system proposed by Sims and Dahle[2]. These classifications are illustrated by the photomicrographs in Fig. 3.

Globular Type I sulphide distribution was characteristic of all silicon-killed steels including those receiving calcium or vanadium additions. The sulphide inclusions in the commercial steels with less than 0.01 per cent residual titanium were also globular. This inclusion distribution

Table 1

COMPOSITION OF COMMERCIAL STEELS TESTED

Heat No.*	Composition, per cent							Deoxidation Treatments	
	C	Mn	Si	S	P	Mo	Residual Deoxidizer	Deoxidant	lb. per ton
158	0.29	1.00	0.30	0.034	0.042	0.42	0.008 Ti	Ti	2.0
9982	0.28	1.01	0.27	0.040	0.035	0.40	0.008 Ti	Ti	2.0
131	0.29	0.99	0.31	0.037	0.032	0.38	0.008 Ti	Ti	2.0
608	0.29	0.95	0.31	0.033	0.036	0.38	0.033 Al	Al	2.8
1141	0.31	1.05	0.32	0.034	0.034	0.33	0.050 Al	CaMnSi Al	2.5 2.8
536	0.29	0.96	0.33	0.033	0.036	0.16	0.089 Al	Al, Boron added	3.0
252	0.27	1.00	0.47	0.031	0.030	0.41	0.002 Al	Al	2.5
1261	0.30	1.01	0.30	0.039	0.035	0.34	0.009 Ti	Ti	2.0
1008	0.28	1.00	0.35	0.035	0.025	0.40	0.007 Ti	Ti	2.0
1092	0.32	0.96	0.30	0.038	0.029	0.34	—	CaMnSi	2.5
1739	0.29	1.00	0.34	0.032	0.030	0.32	—	CaMnSi	2.0

*Steels with heat numbers below 700 were made in an electric furnace; the others were made in an acid open hearth furnace.

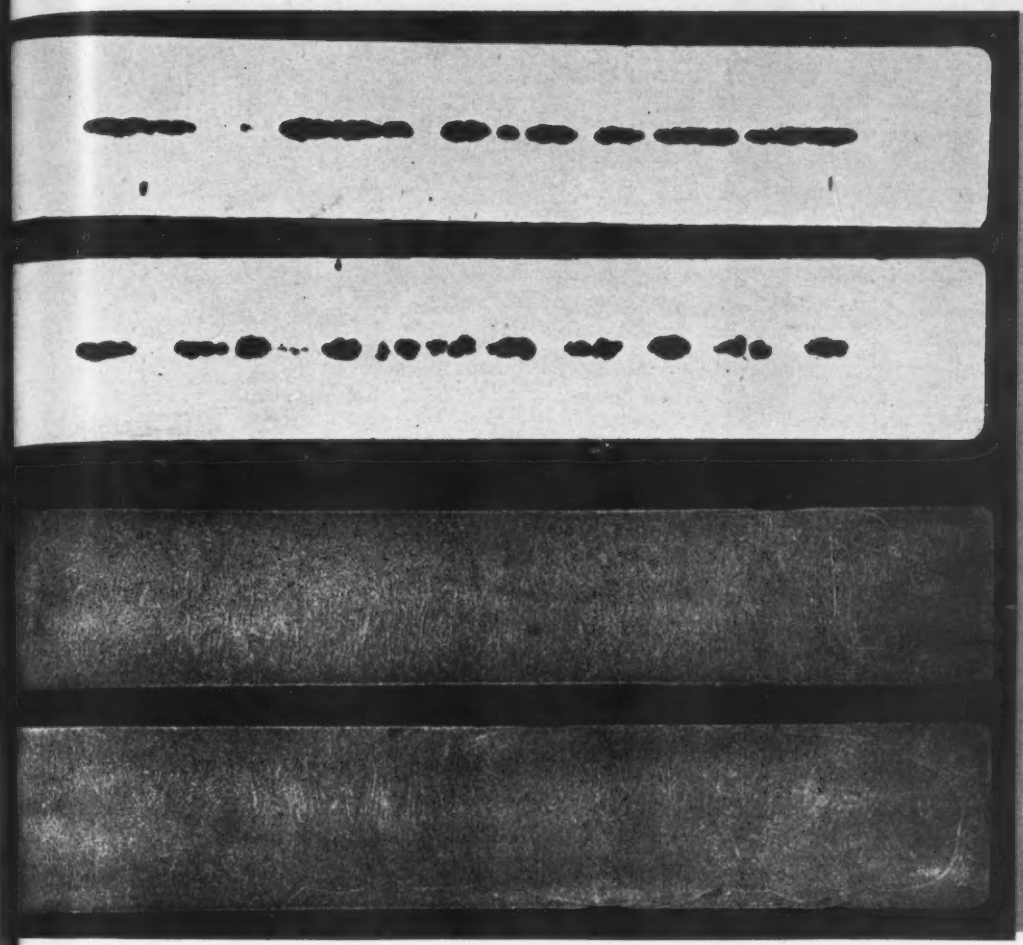


Fig. 2—The two sections at the top were taken from plates cast in an oil-sand mold; the two at the bottom from plates cast in a fire clay-bonded mold. Both steels were made by the same melting practice. ¾X.

is generally considered to have the least harmful effect on ductility.

Manganese sulphide inclusions were comparatively massive and angular in the steels containing at least 0.03 per cent aluminum or 0.05 per cent zirconium. This distribution was classified as Type III, and steels with inclusions of this type generally had good ductility.

Eutectic or chain Type II sulphides were found in steels containing small amounts of aluminum, zirconium, or titanium, and when present, showed embrittlement in both tensile and notched-bar tests. These three elements act similarly in that sufficiently small additions which are largely oxidized will give Type I sulphides, while slightly larger additions form the Type II. Zirconium, like aluminum, forms the more massive Type III sulphides when added in excess, as in steel No. 9.

The five commercial steels, which contained less than 0.01 per cent titanium, had globular Type I sulphides similar to silicon-killed steels. The three laboratory steels (6, 7, 18), on the other hand, containing 0.02, 0.07, and 0.16 per cent titanium, respectively, all had Type II chain or film sulphides. It was concluded, therefore, that the change from film sulphides to massive Type III sulphides is not produced by excess of titanium.

It appeared that the inclusions

Table 2

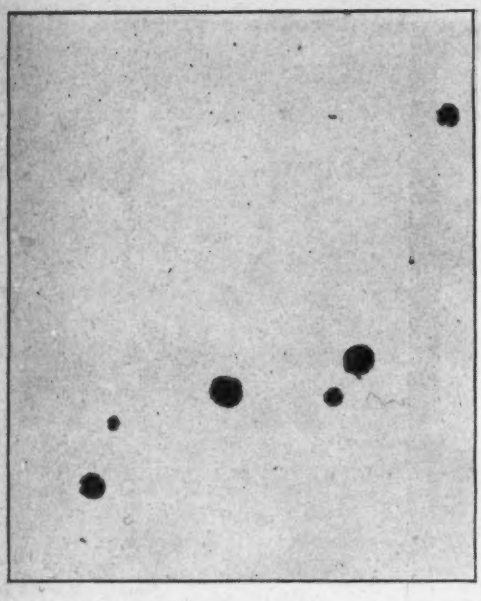
COMPOSITION OF EXPERIMENTAL CAST STEELS TESTED

Casting No.	Composition, per cent					Deoxidation Treatments	
	C	Mn	Si	S	Special Element	Deoxidant	lb. per ton
1	0.27	0.62	0.33	0.026	—	Si only	
2	0.31	0.66	0.38	0.033	0.053 Al	Al	1.5
3	0.31	1.55	0.42	0.036	—	Si only	
4	0.31	1.56	0.42	0.039	0.011 Al	Al	0.4
5	0.29	1.49	0.42	0.037	0.038 Al	Al	1.5
19	0.32	1.30	0.39	0.030	0.120 Al	Al	4.0
6	0.30	1.41	0.35	0.033	0.020 Ti	Ti	1.0
7	0.31	1.51	0.44	0.032	0.070 Ti	Ti	2.0
18	0.30	1.59	0.60	0.018	0.16 Ti	Ti	5.0
8	0.31	1.42	0.33	0.036	0.053 Zr	Zr	1.5
9	0.27	1.37	0.42	0.036	0.080 Zr	Zr	3.0
10	0.28	1.29	0.39	0.040	0.110 V	V	2.0
11	0.32	1.45	0.40	0.036	—	Ca	2.0
12	0.28	0.65	0.38	0.030	1.54 Ni	Si only	
13	0.30	0.68	0.36	0.041	1.55 Ni, 0.04 Al	Al	1.5
15	0.32	0.65	0.33	0.044	1.55 Cu, 0.02 Al	Al	1.5
16	0.16	1.00	0.97	0.033	1.67 Cu	Si only	
17	0.19	0.89	0.81	0.035	1.67 Cu, 0.03 Al	Al	1.5

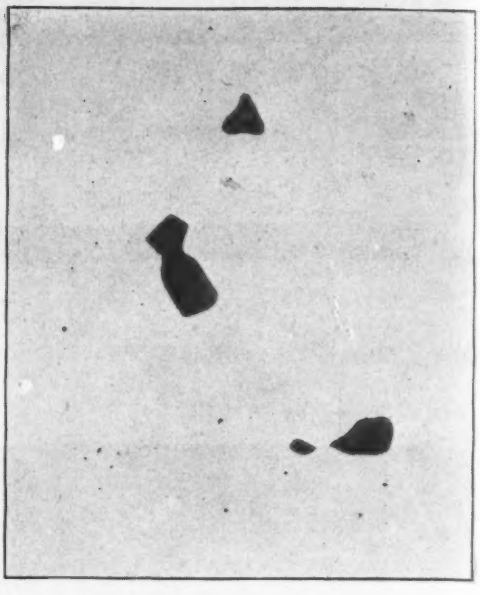
Table 3

PROPORTIONS OF INGREDIENTS USED IN MOLD MIXTURES FOR EXPERIMENTAL CASTINGS

Components	Mixture	
	Oil Sand	Dry Sand
Glass rock sand, lb.	80.0	88.0
Western bentonite, lb.	0.6	—
Silica flour, lb.	7.0	—
Corn flour, lb.	1.3	—
Water, qt.	2	3
Core oil, qt.	1	—
Fire clay, lb.	—	11.0



Globular sulphides, Type I.



Angular sulphides, Type III.

Eutectic or film sulphides, Type II.

Eutectic or film sulphides, Type II.

Fig. 3—Characteristic occurrence of sulphide inclusions in cast steels, classified in three types. Unetched. 1000X.

became increasingly finer and more continuous as the titanium content increased. The photomicrograph in Fig. 4 shows the sulphide distribution in the steel with 0.16 per cent titanium. These inclusions were extremely fine and were light tan or pink in color instead of the usual dove-gray sulphides high in manganese.

The belief that the change in shape and color indicated that they were titanium sulphides was strengthened when evolution analyses gave sulphur values about half of those for other steels made with the same melting practice. As would be expected from the inclusion distribution, this steel was brittle in mechanical tests. The low-carbon ferrotitanium used in making the laboratory steels contained about 8.6 per cent aluminum, so this steel (No. 18) probably had an appreciable residual aluminum content.

In addition to sulphides, the steels contained other inclusions distinctive of their finishing treatments. All of the silicon-killed steels, including those treated with calcium compounds, contained impure silicates. All of the calcium-treated steels had "eyes" or dark spots in the globular sulphides, which seems to be a characteristic effect of this element. The appearance of such sulphides is illustrated by the photomicrograph in Fig. 4.

Inclusion Types

Aluminum-killed steels contained some small alumina inclusions. The heats deoxidized with zirconium contained random clusters of zirconium silicates, as shown in Fig. 4. The zirconium steels were the dirtiest of the steels studied.

Induction furnace steels contained more inclusions than the commercial materials, probably because of the high-oxygen content of the charge. Steels 1261 and 1739 had more inclusions than the other manganese-molybdenum commercial steels. One of these open hearth steels was deoxidized with titanium and the other with a calcium-manganese-silicon alloy.

All of the steels were examined carefully in the etched condition at various magnifications. The microstructures of representative steels are shown in Figs. 5 and 6. Little difference existed in the amount of free ferrite or the degree of spheroidization of similar steels receiving the same quench and draw treatment.

Some of the steels had a more pronounced pattern or network caused by segregation of manganese, but this had no discernible effect on the properties. The photomicrographs for the normalized and drawn condition show that the two best medium-manganese steels had a finer actual grain size than the others. Both steels contained appreciable amounts of residual aluminum.

Titanium steels were equally fine grained but had inferior ductility and toughness because of the Type II inclusion distribution. No consistent differences were found between the microstructures of the steels which were embrittled at low temperatures and those which were relatively unaffected.

Tensile Tests. Tensile tests were made on the induction furnace steels in the normalized and drawn, and the quenched and tempered conditions. The same heat treatments were also used for the notched-bar samples. Identical heat treatments were used on steels of the same grade in order to conserve stock and time.

It is realized that the heat treatments were not ideal for all steels, and the comparisons may be unfair to certain steels which received unfavorable heat treatments. The data given in Table 5, obtained on specimens taken from the top of the 1⅛-in. plates, show that the steels had normal properties for their grade and heat treatment.

Grade "B" steels and those with 1.55 per cent nickel or copper had lower strengths than the medium-manganese steels in the conditions tested. The copper-manganese-silicon steels were tested at somewhat higher strengths than the other steels, but gave good elongation and reduction in area values.

Ordinarily the steels gave better

Table 4

HARDENABILITY DATA FOR EXPERIMENTAL CAST STEELS

Sample No.	Carbon, per cent	ASTM Grain Size*	Special Element or Deoxidizer	Ideal Diameter, in.	End-Quench Test Data — Rockwell "C" Hardness Indicated, in. at Distances					
					Surface	1/16	1/8	1/4	3/8	3/4
GRADE "B" STEELS										
1	0.27	6	Si	0.80	45	43	37	15	11	—
2	0.31	7	+Al	0.83	45	43	24	12	9	—
MEDIUM-MANGANESE STEELS										
3	0.31	5	Si	1.74	49	48	47	44	38	22
4	0.31	7	Al	1.54	49	48	46	38	29	18
5	0.29	9	Al	1.36	48	47	45	29	20	13
19	0.32	9	Al	1.63	49	48	48	41	33	21
6	0.30	9	Ti	1.13	49	48	47	34	24	15
7	0.31	8	Ti	1.32	48	46	44	35	27	18
18	0.30	9	Ti	1.64	49	48	44	32	23	18
8	0.31	6	Zr	1.45	48	47	46	40	29	18
9	0.27	6	Zr	1.35	48	48	47	42	29	17
10	0.32	7	V	1.53	48	48	46	34	25	20
11	0.33	5	(Ca)	1.65	49	49	48	43	37	24
1.55 PER CENT NICKEL OR COPPER STEELS										
12	0.28	6	Ni+Si	1.40	48	46	44	32	20	12
13	0.30	8	Ni+Al	1.47	49	48	45	22	17	10
15	0.32	8	Cu+Al	1.35	49	48	38	17	17	14
COPPER-MANGANESE-SILICON STEELS										
16	0.16	7	Si	1.61	41	40	38	22	22	15
17	0.19	8	Al	1.65	41	37	28	14	14	13
MANGANESE-MOLYBDENUM STEELS										
158	0.29	5	Ti	2.82	Hardenabilities calculated according to Grossmann's method[3]					
9982	0.28	5	Ti	2.60						
131	0.29	5	Ti	2.58						
608	0.29	8	Al	2.23						
1141	0.31	9	Al	2.22						
536	0.29	8	Al+B	2.58						
252	0.27	8	Al	2.28						
1261	0.30	5	Ti	2.52						
1008	0.28	5	Ti	2.74						
1739	0.29	6	Si	2.28						
1092	0.32	6	Si	2.25						

*ASTM grain size was determined for actual heat-treating schedule.

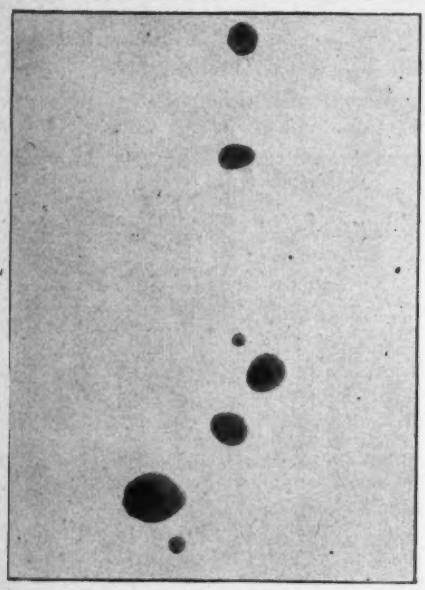


Fig. 4—Photomicrographs showing unusual inclusions found in three experimental steels. Unetched.

Top—Fine eutectic sulphides in high-titanium (0.16 per cent Ti) steel. 400X.

Center—"Bird's eye" sulphides in calcium-treated steel. 500X.

Bottom—Clusters of zirconium oxides and silicates (0.05 per cent Zr). 1000X.

ductility values in the quenched and tempered condition than they did after the other heat treatment. There were no consistent differences in the tensile properties of the steels deoxidized with aluminum and those which had been silicon killed.

Titanium-bearing steels (Nos. 6, 7, 18) and the steel with 0.05 per cent zirconium had the poorest ductility of the experimental steels. The brittleness of the titanium steels, which increased with increasing amounts of this element, is attributed to the presence of intergranular sulphides. Zirconium steel (No. 8) had an inordinate oxide inclusion content which probably had a deleterious effect. The aluminum-killed steel which contained film sulphides (No. 4) had the poorest ductility of the other steels.

Data for the quenched and drawn samples show that the titanium and vanadium steels (Nos. 6, 7, 18, 10) had considerably higher yield strengths and slightly higher ultimate strengths than the other medium-manganese steels. The fact that a high yield strength-ultimate strength ratio was obtained with only 0.02 per cent titanium is somewhat surprising. The high-yield ratio is attributed to a fine dispersion of titanium or vanadium carbides, because aluminum-killed steels of similar grain size had normal yield-strength ratios.

The fact that the higher ratios were not obtained in the normalized and drawn specimens shows that the effect varies with heat treatment. Experience on wrought titanium steels[3] confirms this belief, and it appears that the effect is more pronounced with manganese contents of over one per cent.

Notched-Bar Tests. Charpy notched-bar specimens were broken at temperatures between 75° F. and −100° F. to determine the susceptibility of the different steels to low-temperature embrittlement. The samples were cooled 3° F. below the testing temperature in a bath of dry ice and acetone and held 20 min. before testing.

Previous work indicated that this amount of supercooling compensated for the warming-up which occurred when the samples were transferred to the testing machine. Three or more bars were broken at each test temperature, and the reproducibility of the values was generally good. Test values are given in Tables 6, 7, and 8 and, as would be expected, the tougher samples gave a little more scatter.

Manganese-Molybdenum Steels

Table 9 gives a comparison of the notched-bar values and other characteristics of the manganese-molybdenum steels. The materials are listed in increasing order of embrittlement at low temperatures. The minimum values at various temperatures were used, because they are the safest for comparison.

The data show that the six steels which were made without aluminum were similar in most respects, except for their low-temperature impact behavior. Three of them were the best, and three of them were the worst of the series when tested at −80° F. The steels were alike in being coarse grained and in the Type I distribution of the sulphide inclusions.

All of the steels gave Charpy values in excess of 30 ft.-lb. in the room temperature tests. The data show that these steels varied somewhat in hardenability, hardness, and grain-coarsening tendencies, but that none of the variations were consistently related to their behavior in notched-bar tests.

The four aluminum-killed steels gave lower notched-bar values at room temperature than the other

Table 5

MECHANICAL PROPERTIES OF HEAT TREATED EXPERIMENTAL CAST STEELS

Casting No.	Heat* Treatment	Deoxidizer, per cent	Hardness, Rockwell "B"	Average Vee-Notch Charpy Value, ft. lb.	Elongation in 2 in., per cent	Reduction in Area, per cent	Yield Strength, (0.2% offset) psi.	Ultimate Tensile Strength, psi.
GRADE "B" STEELS								
1	a	Si only	71	30.0	33.0	47.8	40,250	70,500
2	a	0.05 Al	78	34.0	25.0	44.1	47,500	75,750
MEDIUM-MANGANESE STEELS								
3	b	Si only	88	21.0	30.0	55.1	65,750	92,500
4	b	0.01 Al	88	25.0	26.5	46.0	65,500	93,250
5	b	0.04 Al	88	50.0	31.0	57.3	65,500	91,750
19	b	0.15 Al	84	44.5	28.5	52.8	59,000	87,750
6	b	0.02 Ti	89	24.5	26.5	44.9	62,500	94,750
7	b	0.07 Ti	92	24.0	25.0	40.2	66,000	96,000
18	b	0.16 Ti	84	12.5	18.8	22.4	64,750	87,500
8	b	0.05 Zr	88	29.5	25.5	40.4	60,750	93,000
9	b	0.08 Zr	80	23.0	25.0	51.2	51,000	80,000
10	b	0.11 V	84	32.0	31.0	56.8	55,000	84,500
11	b	Ca treated	84	22.0	32.0	56.5	49,000	87,000
1.55 PER CENT NICKEL OR COPPER STEELS								
12	b	Si only	78	31.0	31.0	49.3	48,500	78,000
13	b	0.04 Al	80	34.5	32.0	56.2	50,000	77,000
15	b	0.02 Al	86	27.5	28.0	44.9	62,000	82,250
COPPER-MANGANESE-SILICON STEELS								
16	c	Si only	92	15.5	27.0	60.3	70,750	93,250
17	c	0.03 Al	93	29.0	25.0	50.6	78,250	96,500
GRADE "B" STEELS								
1	d	Si only	77	24.0	25.5	46.6	44,250	71,750
2	d	0.05 Al	82	41.0	31.5	54.4	57,750	79,000
MEDIUM-MANGANESE STEELS								
3	e	Si only	89	64.0	29.0	64.0	67,500	90,500
4	e	0.01 Al	89	27.0	23.0	46.6	66,750	88,750
5	e	0.04 Al	90	55.0	29.5	60.6	68,750	88,750
19	e	0.15 Al	90	42.0	25.0	55.0	65,750	87,250
6	e	0.02 Ti	91	26.0	23.5	45.8	76,750	92,250
7	e	0.07 Ti	91	22.5	21.5	37.3	77,500	93,750
18	e	0.16 Ti	90	9.5	20.5	28.5	78,750	92,000
8	e	0.05 Zr	88	47.5	22.5	37.3	67,500	90,750
9	e	0.08 Zr	89	42.0	27.0	53.8	62,750	87,500
10	e	0.11 V	92	42.0	25.0	58.3	74,500	94,250
11	e	Ca treated	91	54.0	24.0	60.1	69,000	92,500
1.55 PER CENT NICKEL OR COPPER STEELS								
12	e	Si only	82	31.0	25.5	43.8	51,250	78,000
13	e	0.04 Al	85	36.0	31.5	60.3	56,750	82,500
15	e	0.02 Al	88	34.0	30.0	56.0	63,250	85,000
COPPER-MANGANESE-SILICON STEELS								
16	f	Si only	98	23.0	23.0	56.0	91,000	118,250
17	f	0.03 Al	96	38.0	23.0	50.6	85,750	103,500

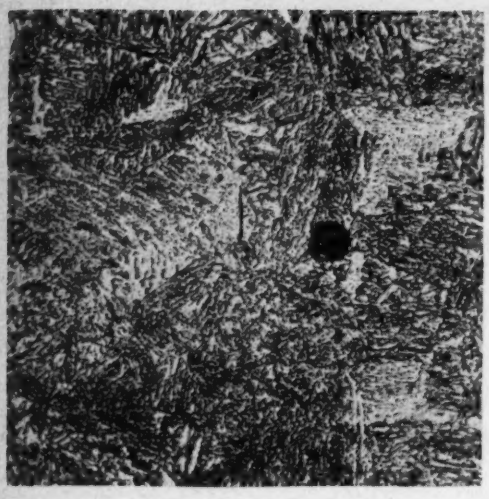
*Heat Treatment. All raw castings were heated 2 hr. at 1800° F. and air cooled before receiving treatments indicated as follows:
a. 1 hr. at 1625° F., air cooled, tempered 2 hr. 1200° F. air cooled.
b. 1 hr. at 1575° F., air cooled, tempered 2 hr. 1200° F., air cooled.
c. 1 hr. at 1600° F., air cooled, tempered 2 hr. 1000° F., air cooled.
d. 1 hr. at 1625° F., water quench, tempered 2 hr. 1250° F., air cooled.
e. 1 hr. at 1575° F., water quench, tempered 2 hr. 1250° F., air cooled.
f. 1 hr. at 1600° F., water quench, tempered 2 hr. 1000° F., air cooled.

Table 6

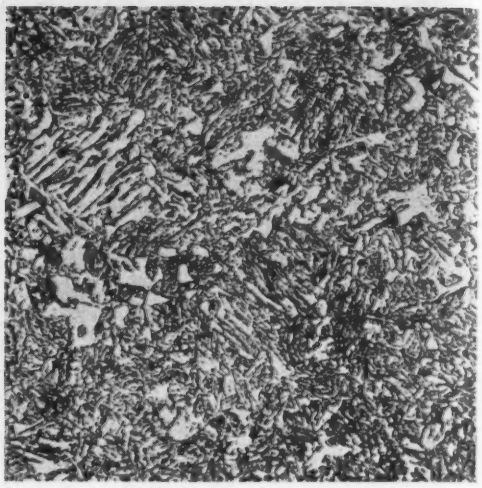
KEYHOLE NOTCH CHARPY IMPACT VALUES OBTAINED ON TEN MANGANESE-MOLYBDENUM STEELS IN THE QUENCHED AND TEMPERED CONDITION, AT TEMPERATURES BETWEEN 75° AND −80° F.

Testing Temperature, ° F.	Steel Heat No. 158	9982	131	608	1141	536	252	1261	1008	1739
	Charpy Impact Value, ft.-lb.									
75	38, 38	41, 39	33, 32	29, 28	28, 28, 26	26, 25, 24, 23	16, 15	36, 33	41, 41, 39, 37	42, 40
32	40, 38	40, 38	34, 32	26, 25	29, 27, 25	27, 26	16, 15	36, 33	40, 40	41, 40
0	37, 35	35, 33	32, 32	—	29, 28, 27	24, 24	15, 15	—	37, 32	—
−20	30, 30	34, 34	—	25, 24	25, 25, 22	26, 26, 26	—	34, 20	31, 25	34, 33
−30	33, 32	33, 28	34, 31	23, 23	—	26, 24, 22, 19	15, 13	24, 24	34, 33	38, 33, 29
−40	34, 33	29, 27	—	—	24, 22, 21	24, 24, 20	—	30, 29	31, 31	37, 7, 5
−50	34, 28	33, 30	30, 29	21, 20	—	23, 22	14, 14	—	31, 28, 25, 6	—
−60	30, 27	26, 23	—	21, 19	25, 23, 21	22, 20, 17	—	30, 22	27, 26	32, 31, 28, 18
−70	28, 28	24, 24	27, 24	19, 16	—	20, 13, 12	—	25, 22	30, 25, 5, 3	34, 30
−80	27, 26	27, 24	26, 24	19, 18	20, 19, 19	19, 19, 18	14, 12	23, 5, 4	30, 22, 16, 11	16, 6, 6

NOTE: Heat treatments were carried out on keel-block coupon 1¼x1¼x14 in.
Heated 2 hr. at 1800° F., air cooled.
Heated 2 hr. at 1600° F., water quenched.
Heated 5 hr. at 1240° F., air cooled.

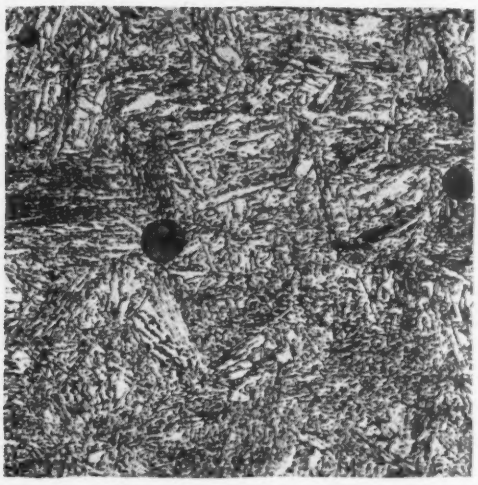


Steel 9982 — 0.008 per cent Ti



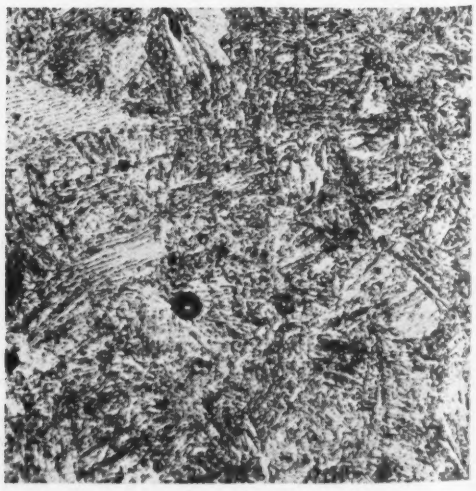
Steel 252 — 0.002 per cent Al

Steel 131 — 0.008 per cent Ti



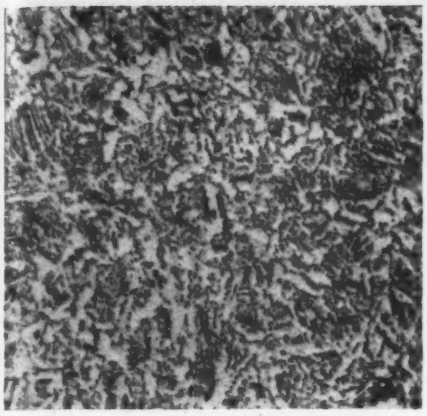
Steel 1008 — 0.007 per cent Ti

Steel 1141 — 0.050 per cent Al



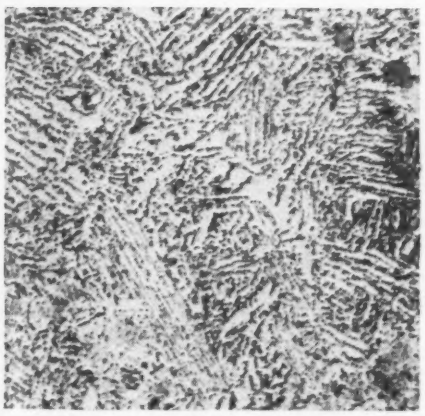
Steel 1739 — 0.340 per cent Si

Fig. 5—Microstructures of manganese-molybdenum steels (water quenched from 1600° F. and tempered at 1240° F.). Steels shown in column at left were not so badly embrittled at low temperatures as those shown in column at right. Nital etch. 500X.

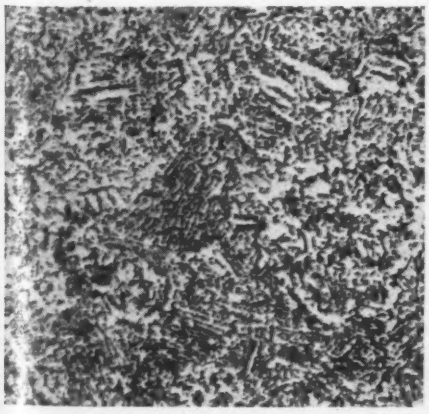


Steel 5 0.04 per cent Al

Steel 11 Silicon killed



Steel 9 0.08 per cent Zr



Steel 6 0.02 per cent Ti

steels, but were not embrittled by temperatures down to −80° F. The fact that these fine-grained steels were inferior in notched-bar properties to the others at temperatures above −40° F. is contrary to results obtained by some other investigators[4,5,6].

Aluminum additions were responsible for the finer grain size and resistance to grain growth exhibited by these steels. Except for the boron steel (No. 536), these materials had lower hardenability than the other group. Steel 252 was so embrittled by film sulphides that decreasing temperatures had practically no effect on the Charpy values.

The data showed that the low-temperature properties of a heat were not reflected consistently by any other property measured. The results also indicated that different melting methods or slight differences in microstructures did not confer any specific effects measured by notched-bar tests.

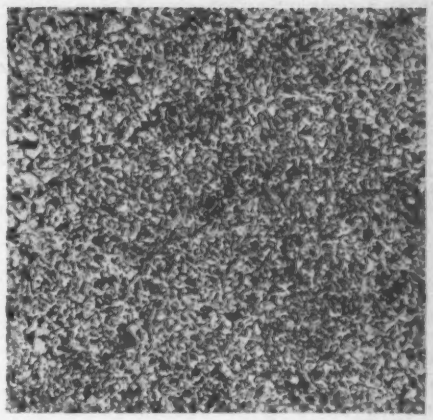
Left — Water quenched 1575° F., tempered 1250° F.

Fig. 6—Microstructures of medium-manganese steels. The two steels at top in each group were least susceptible, and those at the bottom were the most susceptible to low-temperature embrittlement of 11 similar steels tested. Nital etch. Left—500X. Right—100X.

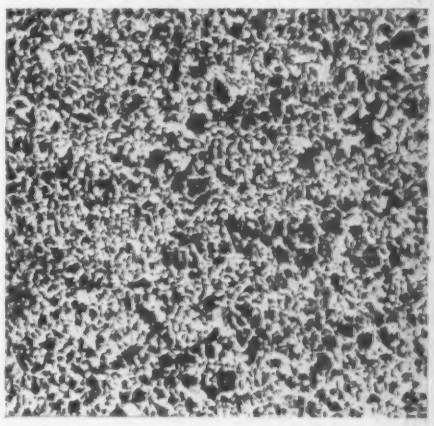
Right — Normalized 1575° F., tempered 1200° F.

All of the aluminum-killed steels had poorer room-temperature Charpy properties than the other steels but were quite resistant to embrittlement by low temperatures. Three of these steels were made in an electric furnace and the fourth was an open hearth steel.

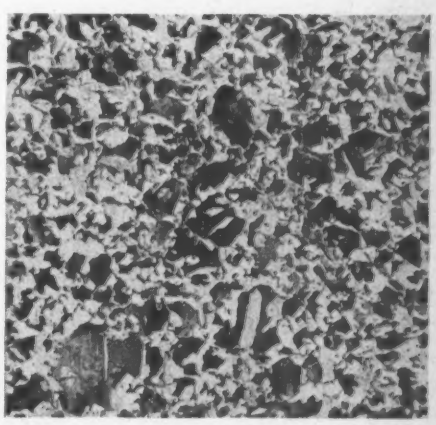
Standard keyhole-notch specimens were used in testing the commercial steels for comparison with results available on other steels of this grade. During this phase of the investigation, some of the materials were also tested with other types of specimens. Figure 7 shows that tests with standard and double-width specimens led to the same conclu-



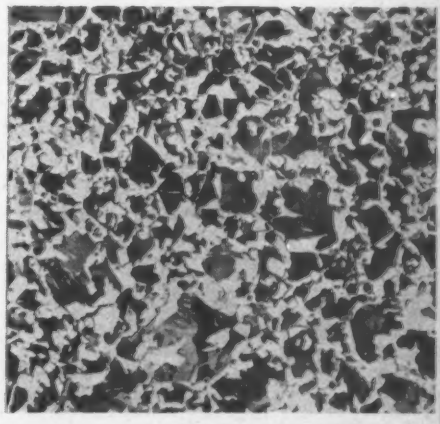
Steel 5 0.04 per cent Al



Steel 19 0.12 per cent Al



Steel 9 0.08 per cent Zr



Steel 3 Silicon killed

Table 7

VEE-NOTCH CHARPY IMPACT VALUES OBTAINED ON 18 CAST STEELS TESTED IN THE NORMALIZED AND DRAWN CONDITION AT TEMPERATURES BETWEEN 75° AND −100° F.

Steel No.	Heat Treatment*	Testing Temperature, ° F. 75	32	0	−20	−40	−60	−80	−100
		Charpy Impact Values, ft.-lb.							
GRADE "B" STEELS									
1	a	35, 31, 29, 28	20, 17, 17	8, 8, 6, 5	6, 6, 5, 4	4, 3, 3, 2	—	—	—
2	a	36, 34, 33, 32	19, 19, 16	12, 12, 9	11, 11, 8	7, 7, 7, 6	6, 5, 5, 5	—	—
MEDIUM-MANGANESE STEELS									
3	b	23, 20, 19	13, 12, 12	6, 5, 4, 3	3, 2, 2	6, 2, 2	3, 3, 1, 1	1, 1, 1	—
4	b	25, 25, 25	16, 15, 14	11, 10, 9	7, 7, 6	6, 5, 5, 5	4, 4, 3, 3	4, 3, 3	—
5	b	51, 49, 50	50, 48, 48	35, 34, 31	24, 23, 23	22, 22, 21, 17	17, 16, 16	14, 14, 13, 13	11, 8
19	b	50, 47, 36	31, 27, 22	23, 22, 19	22, 18, 18	13, 12, 11	14, 12, 11, 6	10, 9, 9, 7	7, 6, 6
6	b	25, 25, 24, 24	21, 18, 17	15, 14, 13	10, 9, 9	9, 8, 7, 7	7, 5, 5, 4	3, 3, 2	—
7	b	26, 25, 24, 22	22, 22, 21	16, 15, 15	12, 11, 11	8, 8, 7, 6	6, 6, 5, 4	—	—
18	b	14, 13, 12, 11	11, 10, 10	10, 9, 8, 7	7, 7, 7, 5	5, 5, 5, 4	5, 4, 4, 4	—	—
8	b	32, 29, 29, 29	20, 19, 16	14, 13, 10, 10	11, 8, 8	11, 10, 10, 7	5, 4, 4, 3	—	—
9	b	24, 22, 22, 22	13, 13, 12	7, 7, 7	6, 5, 5	4, 3, 3	3, 2, 2	—	—
10	b	38, 38, 34, 30	23, 22, 22	16, 12, 12	14, 11, 8	8, 8, 7	8, 8, 5	4, 4, 4	—
11	b	23, 23, 23, 21	16, 15, 14	12, 9, 8	9, 8, 6	8, 7, 5	6, 5, 5	5, 4, 4	—
1.55 PER CENT NICKEL OR COPPER STEELS									
12	b	32, 32, 29, 29	22, 20, 19	18, 16, 15, 13	14, 14, 10, 8	11, 7, 6, 5	5, 5, 4, 4	—	—
13	b	37, 37, 32, 28	25, 25, 24	16, 17, 16	16, 12, 12	11, 10, 10	12, 12, 10	6, 5, 4	—
15	b	30, 29, 25, 24	17, 17, 16	12, 12, 10	10, 9, 8	7, 7, 6	11, 11, 9	4, 3, 3	—
COPPER-MANGANESE-SILICON STEELS									
16	c	17, 14, 14, 13	12, 10, 9	12, 7, 6	8, 8, 6	5, 3, 3	3, 2, 2	—	—
17	c	30, 30, 27	22, 18, 17	14, 14, 12	13, 11, 11	11, 10, 9	8, 8, 7	7, 6, 4	4, 4, 3

*a. 1 hr. 1625° F., air cooled, tempered 2 hr. 1200° F., air cooled.
*b. 1 hr. 1575° F., air cooled, tempered 2 hr. 1200° F., air cooled.
*c. 1 hr. 1600° F., air cooled, tempered 2 hr. 1000° F., air cooled.

Table 8

VEE-NOTCH CHARPY IMPACT VALUES OBTAINED ON 18 CAST STEELS TESTED IN THE NORMALIZED AND DRAWN CONDITION AT TEMPERATURES BETWEEN 75° AND −100° F.

Steel No.	Heat Treatment	Testing Temperature, ° F. 75	32	0	−20	−40	−60	−80	−100
		Charpy Impact Values, ft.-lb.							
GRADE "B" STEELS									
1	d	26, 26, 22, 20	16, 15, 10	11, 10, 9, 5, 4	12, 10, 8, 8	3, 3, 3, 2	—	—	—
2	d	47, 41, 39, 39	24, 23, 23	16, 15, 14	14, 13, 11	11, 11, 11	9, 9, 8, 7	6, 5, 5, 4	4, 4
MEDIUM-MANGANESE STEELS									
3	e	75, 60, 58	59, 49, 48	36, 33, 32	32, 32, 28	21, 19, 18, 17	23, 23, 20, 16	20, 16, 12, 11	14, 9
4	e	28, 27, 24	27, 26, 25	25, 24, 20, 19	17, 17, 17	14, 12, 11	10, 10, 9, 7	9, 8, 7, 7	6, 4
5	e	56, 55, 53	55, 50, 50	51, 48, 43, 39	46, 36, 35	33, 27, 24	22, 21, 20, 20	18, 18, 16, 15	13, 13, 12
19	e	51, 46, 29	44, 29, 25	41, 33, 30	25, 23, 19	23, 22, 22	21,19,14,13,13	18, 16, 12, 11	7, 7, 7
6	e	29, 28, 22	26, 23, 22	27, 25, 24, 17	15, 13, 13	16, 12, 10, 10	8, 7, 7, 6	7, 6, 6, 4	5, 4, 4
7	e	29, 22, 20, 19	27, 21, 18	17, 17, 17	24, 23, 13, 13	11, 10, 10	7, 7, 7, 6	6, 5, 5, 4	5, 4, 4
18	e	10, 10, 9, 9, 9	9, 9, 8	7, 7, 6, 6	7, 6, 6, 6	5, 5, 4, 4	5, 4, 4	—	—
8	e	49, 49, 47, 44	39, 34, 33	25, 23, 21	20, 20, 17	21, 16, 14, 13	17, 16, 16, 14	11, 11, 11, 6	11, 7, 6
9	e	46, 38, 38	48, 31, 20	29, 25, 15	21, 9, 8	6, 6, 6	18, 13, 4	12, 4, 3	7, 5, 2
10	e	44, 40, 35, 27	25, 25, 20	20, 20, 16	17, 16, 14	21, 14, 14	11, 9, 6	6, 5, 4	—
11	e	56, 53, 51	43, 41, 41	31, 30, 29	35, 37, 26	23, 21, 21	23, 20, 15	18, 16, 12	11, 10, 8
1.55 PER CENT NICKEL OR COPPER STEELS									
12	e	32, 32, 30, 30	22, 22, 21	20, 20, 18, 16	19, 18, 13, 12	15, 13, 12, 8	13, 10, 10, 7	6, 4	—
13	e	36, 35, 33	31, 30, 26	26, 26, 20	20, 16, 15	14, 13, 13	12, 10, 8	9, 8, 7	9, 6, 6
15	e	38, 34, 30	36, 34, 34	21, 20, 20	17, 17, 15	16, 13, 12	5, 4, 4	11, 9, 8	6, 5, 4
COPPER-MANGANESE-SILICON STEELS									
16	f	25, 21, 21	16, 15, 15	12, 12, 11	13, 13, 12	11, 10, 7	10, 8	9, 7, 7	7, 5, 3
17	f	38, 38	30, 26, 23	20, 20, 19	16, 14, 12	14, 14, 11	14, 12, 11	11, 10, 9	10, 8, 8

HEAT TREATMENT

d. 1 hr. 1625° F., water quench, tempered 2 hr. 1250° F., air cooled.
e. 1 hr. 1575° F., water quench, tempered 2 hr. 1250° F., air cooled.
f. 1 hr. 1600° F., water quench, tempered 2 hr. 1000° F., air cooled.

Table 9

COMPARISON OF THE LOW-TEMPERATURE NOTCHED-BAR PROPERTIES OF MANGANESE-MOLYBDENUM CAST STEELS WITH OTHER CHARACTERISTICS*

Heat No.	Hardness Rockwell "B"	Hardness Brinell	Residual Deoxidizer, per cent	Sulphide Inclusion Type	Austenite Grain Size 1600° F.	Austenite Grain Size 1750° F.	Austenite Grain-Growth Characteristics	Calculated Hardenability Ideal Diameter, in.	Minimum Charpy Values,[a] ft.-lb. 75° F.	0° F.	−40° F.	−80° F.	Other Values	Break in Impact vs. Temperature Curve
158	94	202	0.008 Ti	I	5	1 & 5	Coarse grain readily coarsened further.	2.82	38	35	33	26	—	None
9982	96	212	0.008 Ti	I	5	5	Coarse grain, not readily coarsened further.	2.60	39	33	27	23	—	None
131	98	225	0.008 Ti	I	5	5		2.58	33	32	29	23	—	None
1092[b]	96	212	Si	I	6	5	Fine grain, not readily coarsened.	2.25	32	28	24	22	—	None
608	91	189	0.033 Al	III	8	7		2.23	26	24	21	16	—	None
1141	97	219	0.050 Al	III	9	9		2.22	25	27	21	19	—	None
536[c]	96	212	0.089 Al	III	8	8		2.58	23	23	20	18	12 at −70° F.	−70° F.
252	98	225	0.002 Al	II	8	7		2.28	15	15	14	11	—	None
1261	92	195	0.009 Ti	I	5	1 & 5	Coarse grain readily coarsened further.	2.52	33	32	29	4	—	−70° F.
1008	96	212	0.007 Ti	I	5	3		2.74	37	32	31	3	—	−50° F.
1739	92	195	Si	I	6	1	Fine grain, readily coarsened further.	2.28	37	33	5	4	—	−40° F.

*All steels were of closely similar composition and were water quenched from 1600° F. and tempered at 1240° F.
a. Tests made on standard keyhole-notch Charpy specimens.
b. The keel blocks from this heat exhibited pinhole porosity.
c. Steel 536 also contained boron.

sions about the properties of steel No. 1008.

Both types of samples showed a fairly uniform drop in test values between 32° F. and −20° F., and considerable scatter at lower temperatures. Although duplicate standard specimens gave good checks at −30° F. and −40° F., a variation would have been encountered if more specimens had been tested.

Plots in Fig. 8 give the data for keyhole and Vee-notched bars of steels Nos. 1092 and 1141. The values for the keyhole specimens decreased uniformly from 30 ft.-lb. at room temperature to about 18 ft.-lb. at −80° F. The drop was about one-third of the room-temperature value for both steels. Values for the Vee-notch specimens started at a higher level for room temperature and decreased about one-half to the same level as the keyhole specimens at −80° F. These data also show that neither steel was temper brittle when heat treated as a keel block 1¼ in. square.

Tests were also made on two wrought steels to determine the effect of specimen dimensions on notched-bar properties. These steels were similar to cast steels in composition but were forged and rolled to ½-in. plate for convenience in obtaining a large number of specimens. The compositions, heat treatment, and tensile properties of the two materials are given in Table 10. The data in Figs. 9 and 10 show that the keyhole-notched specimens gave reasonable agreement in all cases, and the Vee-notched samples of the carbon steel also gave good checks. Data for all types of specimens show that the toughness of both steels decreased gradually with decreasing temperature and that the carbon steel was inferior to the other material. The great variation in values for Vee-notched bars of the manganese-molybdenum steel may indicate that it is more sensitive to unintentional variations in specimen or test conditions.

Specimen Shapes

Work on specimens of different shapes indicated that tests with either of the standard-width Charpy specimens would give the same information concerning low-temperature embrittlement. In most of the tests, the Vee-notched bars gave higher test values at room temperature than keyhole specimens, and equally small values for brittle fracture.

It was concluded, therefore, that the Vee-notched specimens were preferable, because they gave a wider range in values. It seemed desirable to test a larger number of specimens when studying the laboratory steels because of the likelihood of encountering greater scatter with the Vee-notched specimens.

Table 11 gives a comparison of the minimum Charpy values of the laboratory steels and lists the other characteristics of the materials. The steels are grouped on the basis of chemical composition instead of resistance to embrittlement because several grades are represented.

None of the laboratory steels was as tough at low temperatures as the commercial steels containing molybdenum. However, the room-temperature values were normal for the

Table 10

MECHANICAL PROPERTIES AND COMPOSITION OF TWO WROUGHT STEELS USED FOR STUDY OF EFFECT OF SPECIMEN SHAPE ON CHARPY NOTCHED-BAR VALUES

Steel No.	Mechanical Properties* Ultimate Strength, psi.	Yield Strength, psi. (0.2% offset)	Elongation in 2 in., per cent	Brinell Hardness	Composition, per cent C	Mn	Mo	Si	S
10490	93,000	74,250	27.5	185	0.28	0.90	0.30	0.35	0.035
10491	78,000	47,750	36.0	158	0.27	0.67	—	0.40	0.037

*Values are average of two tests on 2.00x0.500x0.500-in. gage-length specimens.
Steel 10490 was heated 2 hr. at 1600° F., water quenched, tempered 5 hr. at 1240° F., and air cooled.
Steel 10491 was heated 2 hr. at 1650° F., and air cooled.

Table 11

COMPARISON OF THE LOW-TEMPERATURE NOTCHED-BAR PROPERTIES OF VARIOUS EXPERIMENTAL STEELS MADE WITH DIFFERENT DEOXIDATION PRACTICE AND TESTED IN TWO CONDITIONS OF HEAT TREATMENT

Casting No.	Hardness, Rockwell "B" N.,D.	Q.,D.*	Residual Deoxidizer, per cent	Sulphide Inclusion Type	Austenite Grain Size 1600° F.	1750° F.	Austenite Grain-Growth Characteristics	Hardenability Ideal Diameter, in.	Minimum Charpy Values, ft.-lb. Quenched and Drawn, ° F. 75	0	−40	−80	Normalized and Drawn, ° F. 75	0	−40	−80
GRADE "B" STEELS																
1	71	77	Si	I	7	2	Fine, readily coarsened.	0.80	20	4	2	—	28	5	2	—
2	78	82	0.053 Al	III	7	5	Fine, less readily coarsened.	0.83	39	14	10	3	31	9	5	—
MEDIUM-MANGANESE STEELS																
3	88	89	Si	I	5	4	Coarse, readily coarsened.	1.74	58	32	17	11	19	3	2	1
4	88	89	0.011 Al	II	7	6	Fine, resistant to coarsening.	1.54	24	19	11	7	25	9	5	3
5	88	90	0.038 Al	III	9	8		1.36	53	39	24	15	45	31	17	13
19	84	90	0.150 Al	III	9	8-5		1.63	29	30	22	11	36	19	11	7
6	89	91	0.020 Ti	II	9	8		1.13	22	17	10	4	24	13	7	2
7	92	91	0.070 Ti	II	8	8		1.32	19	17	10	4	22	15	6	—
18	84	90	0.160 Ti	II	9	9		1.64	9	6	4	—	11	7	4	—
8	88	88	0.053 Zr	III	6	4	Fine, readily coarsened.	1.45	44	21	13	6	29	10	7	—
9	80	89	0.080 Zr	III	6	4		1.35	38	15	6	3	22	7	3	—
10	84	92	0.11 V	I	7	3-4	Fine, readily coarsened.	1.53	27	16	14	4	30	12	7	4
11	84	91	Ca added	I	5	3	Coarse, readily coarsened.	1.65	51	29	21	12	21	8	5	4
1.55 PER CENT NICKEL OR COPPER STEELS																
12	78	82	Si	I	6	3	Fine, readily coarsened.	1.40	30	16	8	4	28	13	5	—
13	80	85	0.04 Al	III	8	7	Fine, resistant to coarsening.	1.47	33	20	13	7	24	16	10	4
15	86	88	0.02 Al	III	8	7		1.35	30	20	12	8	24	10	6	3
PRECIPITATION HARDENED, COPPER-MANGANESE-SILICON STEELS																
16	92	98	Si	I	7	3-4	Fine, readily coarsened.	1.61	21	11	7	7	13	6	3	—
17	93	86	0.02 Al	III	8	8	Fine, resistant to coarsening.	1.65	38	19	11	9	27	12	9	4

NOTE: Tests made on standard vee-notch Charpy specimens.
*N., D.—Normalized and drawn.
*Q., D.—Quenched and drawn.

different grades and comparable to results obtained on keel-block samples.

Quenching usually produced better notched-bar properties at room temperature than the normalizing treatment. The superiority of the quenched and drawn samples was more pronounced at lower testing temperatures. The aluminum-treated steels usually were tougher at low temperatures than their silicon-killed comparison steels, although they were not always superior at room temperature.

Aluminum-killed steels Nos. 5 and 19 were almost as good in the normalized and drawn condition as they were as quenched and drawn. These two medium-manganese steels had the best low-temperature properties of all the laboratory steels. Steel No. 4 with a smaller residual aluminum content was poorer, because it was embrittled by film sulphides. The silicon-killed steels Nos. 3 and 11 were tough at low temperatures in the quenched and drawn condition but brittle as normalized and drawn.

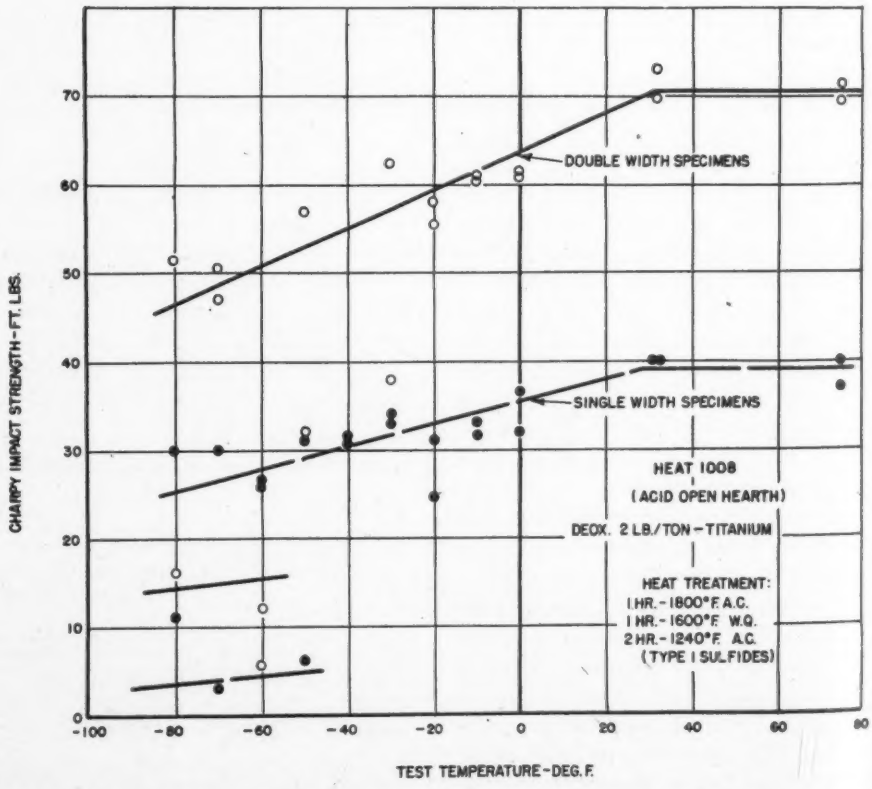


Fig. 7—Low-temperature notched-bar impact strength (Charpy keyhole single and double width specimens.)

Fig. 10 (right) — Low-temperature notched bar properties of a quenched and tempered manganese-molybdenum rolled steel.

This behavior may have been related to their greater hardenability, but none of the other data indicated any relationship between this factor and low-temperature notched-bar properties. The effect of heat treatment on the toughness of zirconium steel No. 8 was similar to that on the silicon-killed steels, although it did not have a high hardenability.

Notched-bar properties of the steels with 1.55 per cent nickel or copper were not so good as those of the better medium-manganese steels. In the quenched and drawn condition, the copper steel was as resistant to low-temperature embrittlement as the nickel steel and nearly as good when normalized and drawn.

Precipitation-hardened steel deoxidized with aluminum (No. 17) had Charpy properties equivalent to the nickel steels, although it had a much higher tensile strength. The Grade "B" steels were the poorest of the materials tested.

Fractures of Notched-Bar Specimens. When notched bar impact specimens break with a completely brittle fracture, they show no deformation, and the fracture surfaces often have a crystalline texture. Tough specimens undergo considerable plastic deformation before rupture and often show a fibrous fracture.

Fractures with a crystalline area

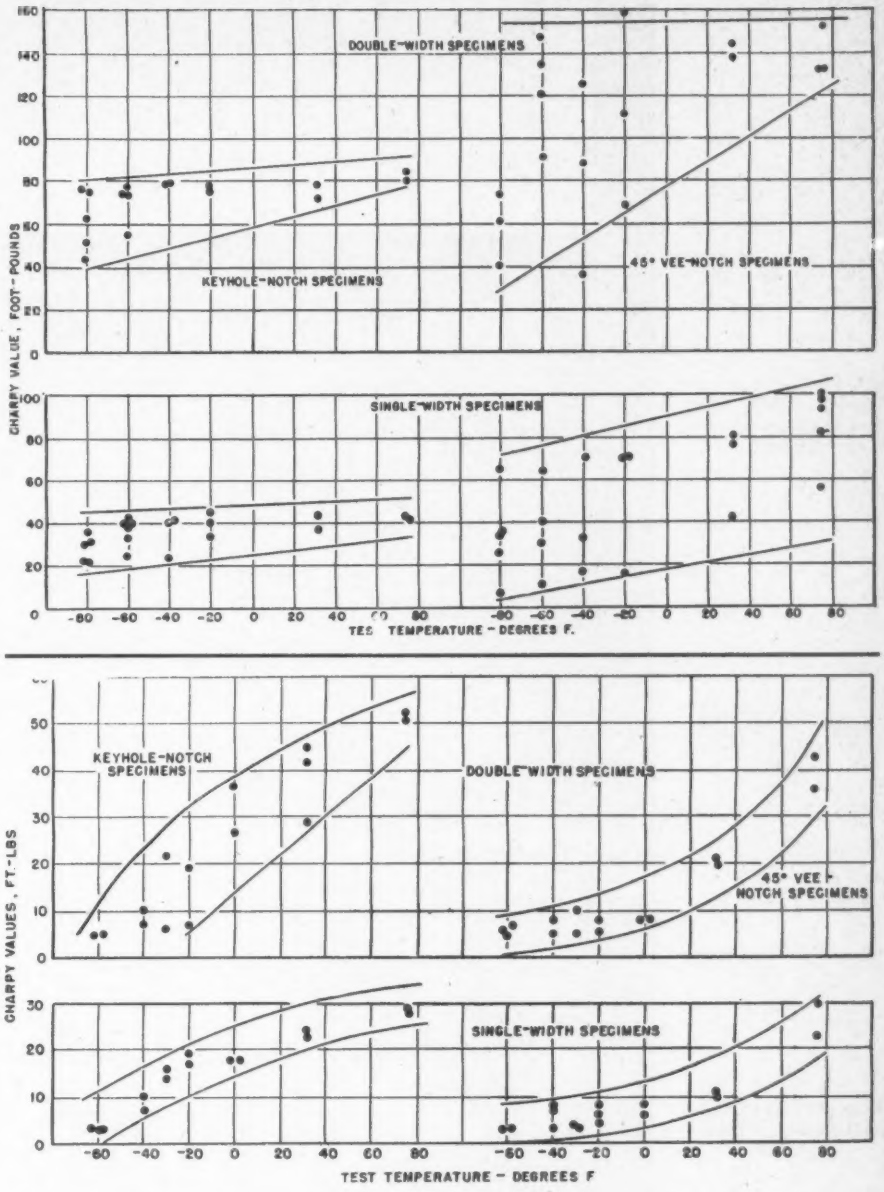
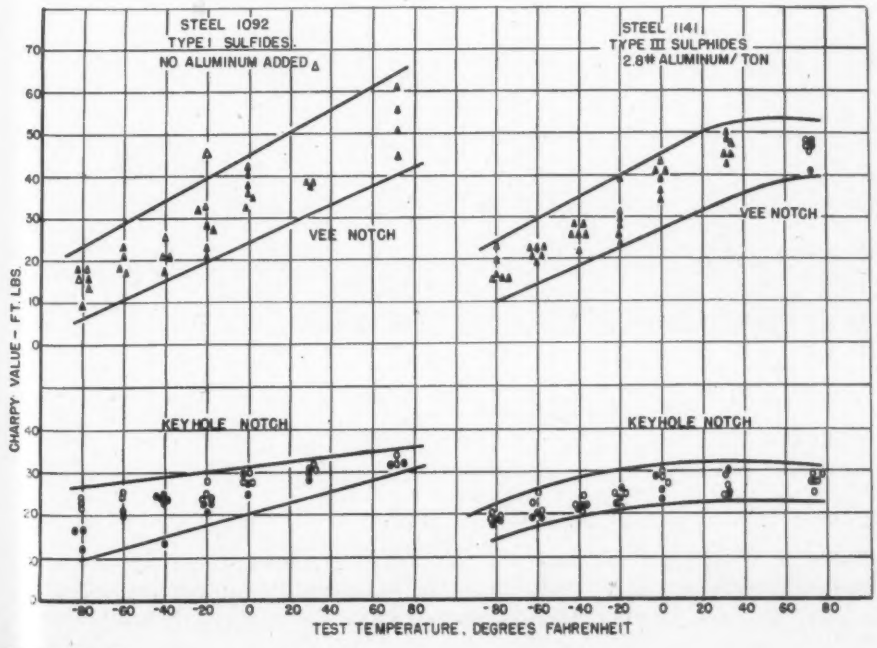


Fig. 9 (above)—Low-temperature notched-bar properties of a normalized, medium-carbon rolled steel.



in the center surrounded by material which deformed before rupture are often observed in the so-called transition zone between ductile and brittle fracture[7]. These facts have led some investigators to conclude that the appearance of the fracture is as important as the energy values in interpreting the results of notched-bar impact tests.

In this investigation, the appearance of fractures of the test bars was noted, and photographs were taken

Fig. 8—Low-temperature notched-bar properties of two manganese-molybdenum cast steels in the quenched and tempered condition. Solid points represent bars furnace cooled from 1240° F. draw; open points represent air-cooled samples.

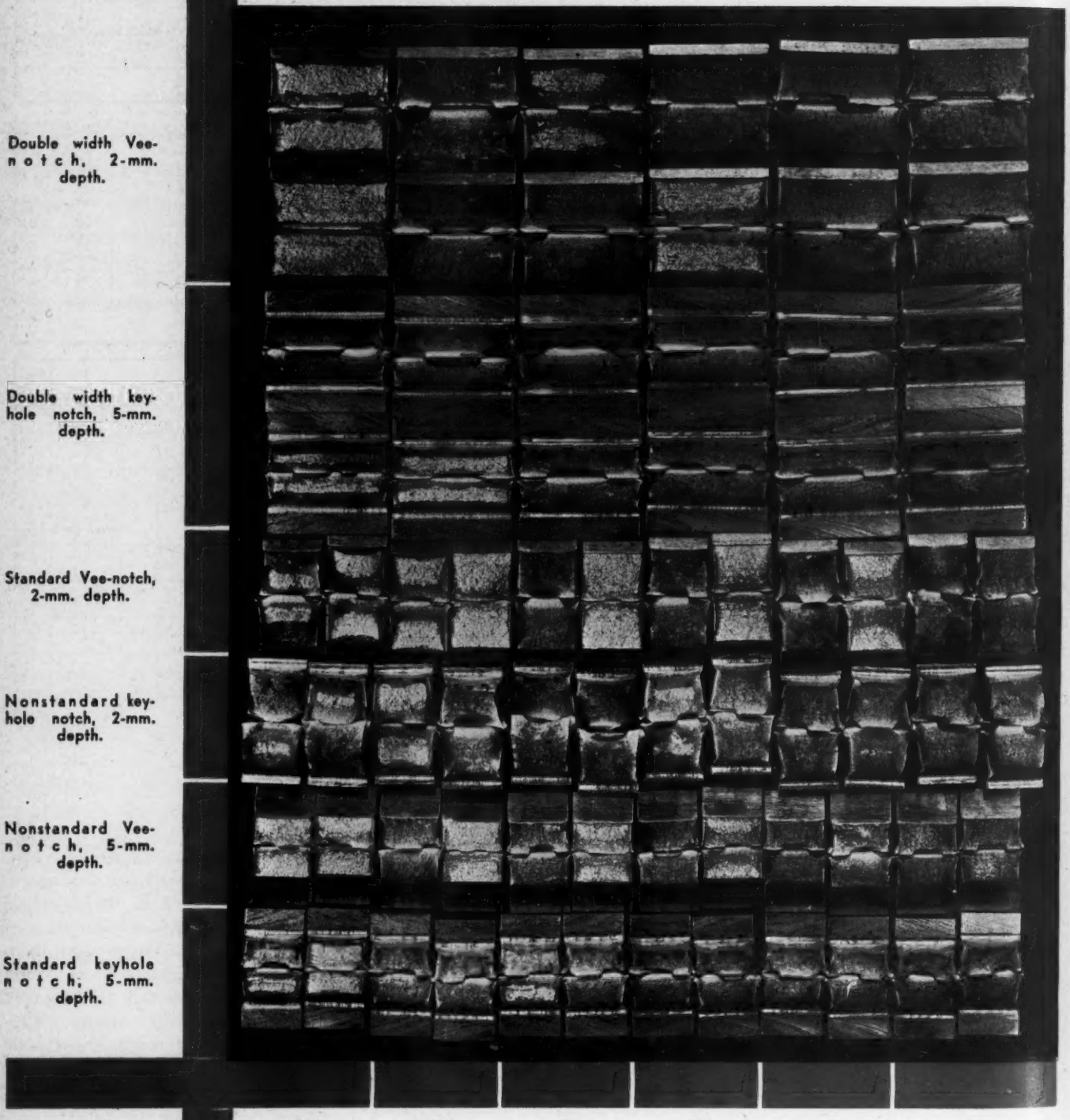


Fig. 11—Appearance of notched-bar fractures for different kinds of specimens from a rolled manganese-molybdenum steel (10490) in the quenched and tempered condition. Actual size.

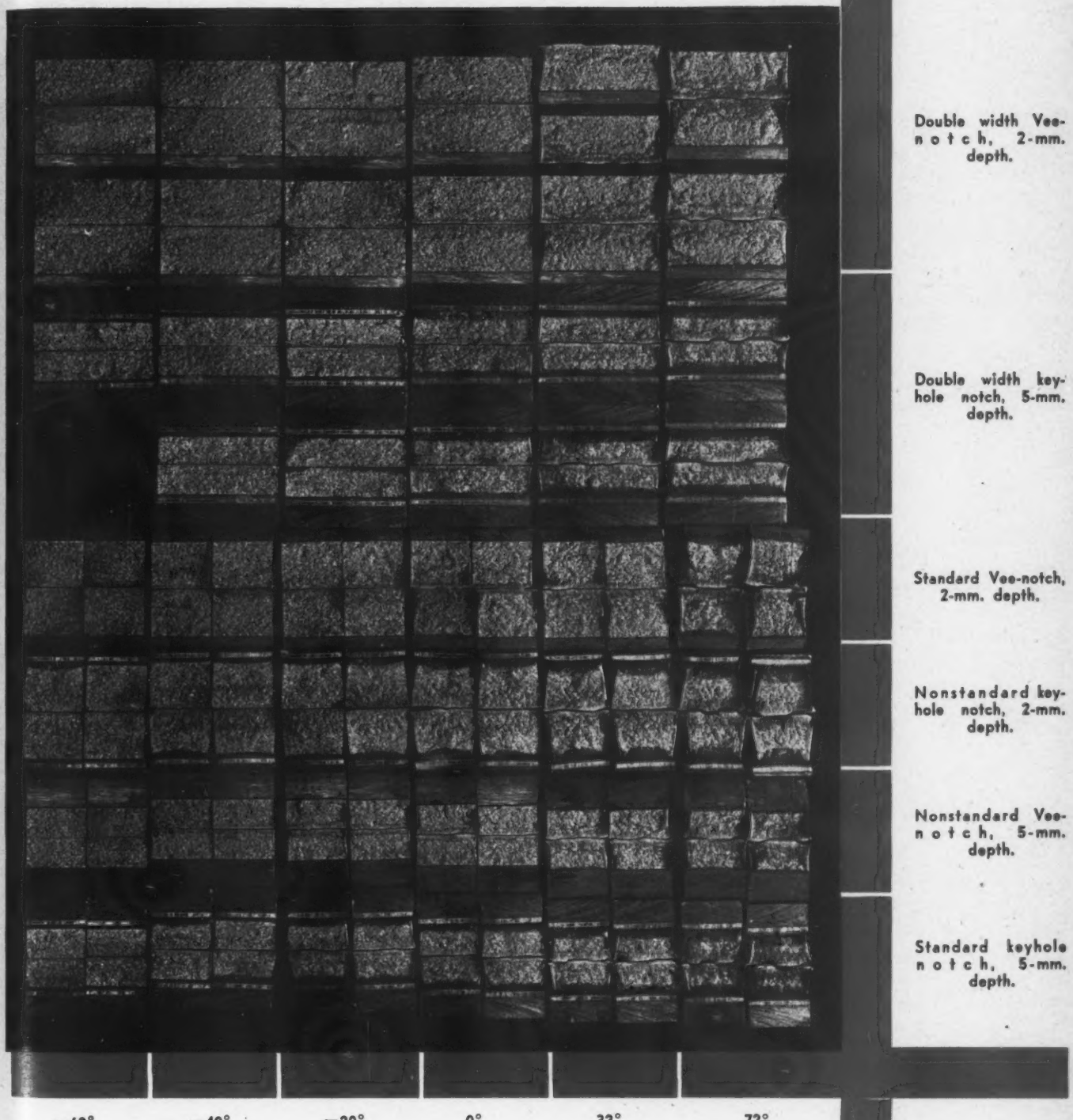


Fig. 12—Appearance of notched-bar fractures for different kinds of specimens from a rolled manganese-molybdenum steel (10490) quenched and tempered. Actual size.

Table 12

HIGHEST TEMPERATURES AT WHICH NOTCHED-BAR FRACTURES SHOWED CRYSTALLINE TEXTURES OR NO APPRECIABLE DEFORMATION AND THE CORRESPONDING CHARPY VALUES

Steel and Treatment*	Start of Crystalline Fracture		Deformation Characteristics	
	Temp., ° F.	ft.-lb.	Temp., ° F.	ft.-lb.
STANDARD CHARPY KEYHOLE SPECIMENS				
536Q	None	—		17.5
131Q	—50	29		23
1261Q	—30	24	Deformed at —80	20
10490Q	—40	23		20
252Q	—80	12		12
1008Q	—10	32	No deformation at —70	3
10491N	+75	28	No deformation at —60	3
STANDARD CHARPY VEE-NOTCH SPECIMENS				
5Q	—20	35	Deformed at —100	12
5A	+32	48	No deformation at —100	8
11Q	—20	26		12
8Q	—20	17		6
10490Q	+32	42	No deformation at —80	6
3Q	—20	28		11
13Q	+75	33		8
10Q	+75	27		6
6Q	—20	13	No deformation at —60	6
7Q	—40	10		6
4Q	0	19		7
17Q	+75	38		11
16Q	+75	21		7
13A	—20	12	No deformation at —40	10
9Q	+75	38		6
7A	—30	8		11
15A	+75	24		8
2Q	—20	11		11
2A	—20	8		8
10491N	+75	23		4
17A	—20	11		11
6A	—20	9	No deformation at —20	9
8A	+75	29		8
10A	+75	30		8
11A	+75	21		6
4A	0	9		6
9A	+32	12		5
3A	+75	19		2
16A	+75	13		11
1A	+75	28	No deformation at 0	5
1W	+75	20		4
DOUBLE-WIDTH KEYHOLE SPECIMENS				
10490Q	—60	55	Deformed at —80	44
1008Q	0	62	No deformation at —60	5.5
10491N	+75	51	No deformation at —20	7
DOUBLE-WIDTH VEE-NOTCH SPECIMENS				
10490Q	—20	60	Deformed at —80	41
10491N	+75	36	No deformation at 0	8

*Heat Treatment. Q—Quenched and tempered; A—Normalized and tempered; N—Normalized.

for record purposes. The photographs in Figs. 11 and 12 show the appearance of the fractures of two steels which were tested at various temperatures with six kinds of specimens.

Figure 10 shows that the crystalline texture appeared at 32°, —20°, —40°, and —60° F., depending upon the shape of the specimen, although all samples deformed considerably at —80° F., the lowest test temperature employed. The standard Vee-notch specimens, which showed a crystalline area at 32° F., deformed considerably more at —80° F. than the double-width Vee-notched and the 5 mm. Vee-notched bars which did not show the crystalline fractures at temperatures above —20° F.

Fracture appearance of another steel is shown in Fig. 12. All six types of specimens gave crystalline fractures at room temperature, although the temperature at which rupture occurred with no deformation varied wtih the specimen shape. The temperature of completely brittle failure varied from 0° to —60° F. for this steel, depending upon the shape of the specimen.

Figure 13 shows that the crystalline fracture appeared in steel No. 1008 at 0° F. in the double-width specimens and at —10° F. in the standard keyhole samples. However, all of the specimens showed some deformation in tests at —80° F.

Data in Table 12 summarize the observations on the temperatures at which crystalline patches, and completely brittle fractures first appeared in notched-bar tests on various steels. It is apparent that crystalline textures were found in samples which gave widely different test values.

Temperatures at which the crystalline patches appeared in a steel bore no relationship to the temperature at which the steel failed without appreciable deformation. The data also show that all of the samples which broke without appreciable plastic deformation, gave test values of 12 ft.-lb. or less. It is believed that much of the energy required for rupture of the specimens which broke with a brittle fracture was absorbed by elastic deformation and in knocking the pieces from the anvil.

Conclusions

1. Susceptibility to low-temperature embrittlement of steels of the same grade was not consistently related to differences in melting practice, deoxidation treatment, inclusion distribution, grain size, or grain-growth characteristics. The slight variations found in hardenability and microstructure of similar steels were without apparent effect on the notched-bar properties.

2. Relative resistance of various steels to low-temperature embrittlement bore no relationship to their room-temperature tensile or notched-bar properties.

3. Quenching usually developed better notched-bar properties than normalizing before drawing to the same strength level. The aluminum-killed steels, which were tough as normalized, did not evidence this response to heat treatment.

4. Fine-grained steels often gave poorer Charpy values at room temperature than coarse-grained steels.

5. In general, the aluminum-killed steels showed less embrittle-

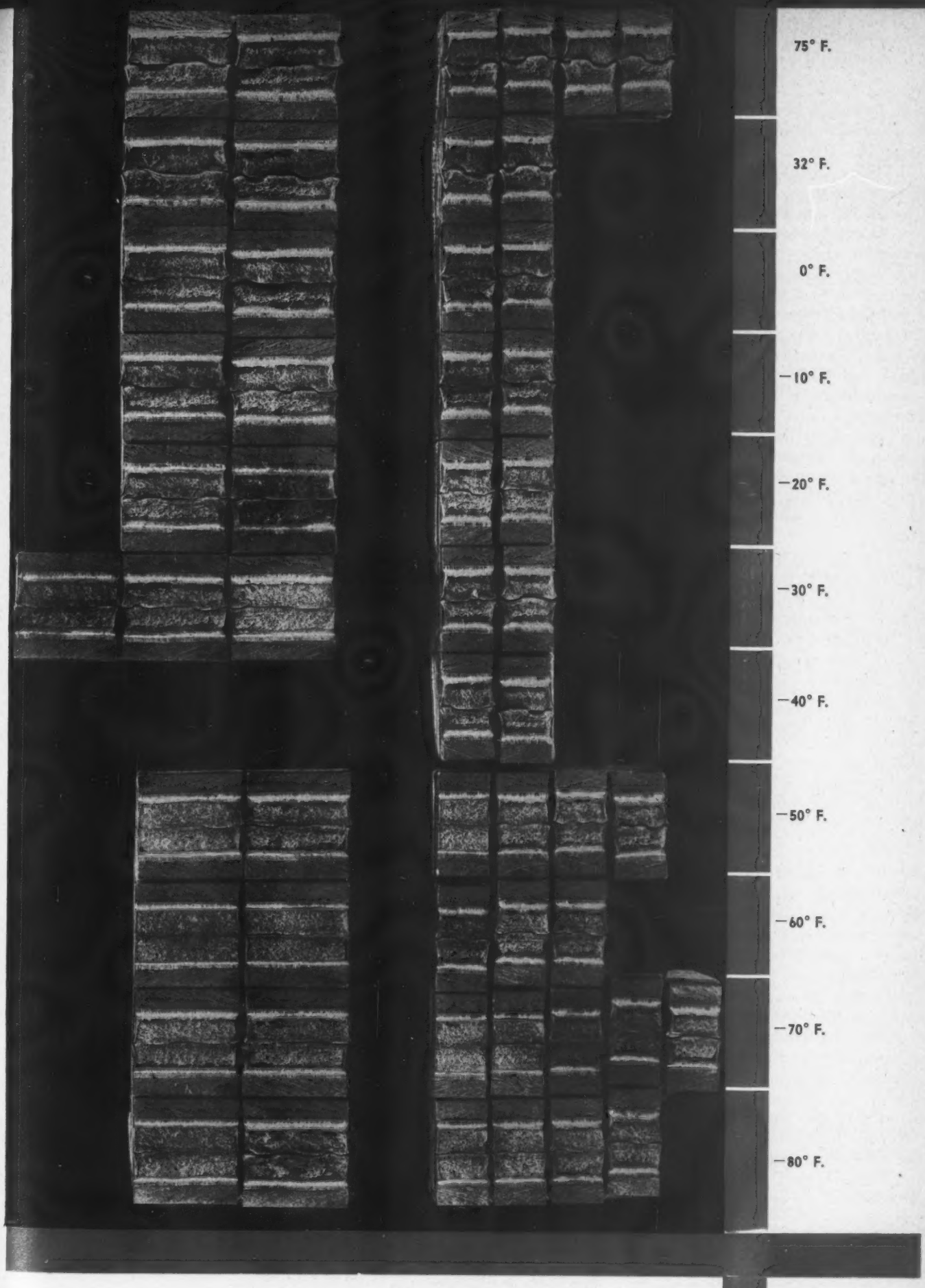


Fig. 13—Appearance of fractures of notched-bar impact specimens of Steel 1008 tested at various temperatures. Actual size.

ment by low temperatures than similar materials deoxidized with other elements.

6. Film sulphide, Type II, inclusions produced poor ductility and Charpy properties at room temperature, but the embrittlement was less noticeable at low temperatures.

7. Steels containing less than 0.01 per cent titanium had globular Type I sulphides; those containing 0.02, 0.07, and 0.16 per cent titanium contained chain or film Type II sulphide inclusions. The undesirable eutectic sulphides persisted in steels containing much higher titanium contents than those usually employed. It appears, therefore, that the action of excess titanium on sulphide distribution is different than the action of aluminum of zirconium.

8. In the steels studied, copper seemed to be as beneficial as nickel in conferring resistance to low-temperature embrittlement. The results on medium-manganese and Grade "B" steels suggested that manganese also improved low-temperature toughness.

9. Porosity encountered in some castings was attributed to gases picked up from core-sand molds. Higher manganese contents, or additions of strong deoxidizers were sufficient to prevent the center-line gas porosity.

Acknowledgment

This investigation was made possible by an appropriation from a fund for research and education established at Battelle Memorial Institute by the Ohio Steel Foundry Co. This fund is to be used for work at the Institute on the technology of the steel foundry, the general dissemination of knowledge in this field, and the education of men skilled in the foundry art. The cooperation of H. R. McCoy and Frank Kiper of the Ohio Steel Foundry Co. in furnishing information and materials, and the assistance of J. A. Finley of the Battelle staff are gratefully acknowledged.

Bibliography

1. M. A. Grossmann: "Hardenability Calculated From Chemical Composition," *Transactions,* AIME, vol. 150, pp. 227-255 (1942).

2. C. E. Sims and F. B. Dahle: "Effect of Aluminum on the Properties of Medium-Carbon Cast Steels," TRANSACTIONS, American Foundrymen's Association, vol. 47, pp. 65-132 (1938).

3. G. F. Comstock: "Some Effects of Heat Treatment on Low-Alloy Titanium Steels," *Transactions,* ASM, vol. 33, pp. 324-337 (1944).

4. C. H. Herty, Jr., and D. L. McBride: "Effect of Deoxidation on the Impact Strength of Carbon Steels at Low Temperatures," *Cooperative Bulletin 67,* Min. & Met. Advisory Boards, Carnegie Institute of Technology, and Bureau of Mines, Pittsburgh, 1934.

5. Philip Schane, Jr.: "Effects of McQuaid-Ehn Grain Size on the Structures and Properties of Steel," ASM, *Grain-Size Symposium,* pp. 1038-1050 (1934).

6. T. N. Armstrong and A. P. Gagnebin: "Impact Properties of Some Low-Alloy Nickel Steels at Temperatures Down to −200° F.," *Transactions,* ASM, vol. 28, pp. 1-19 (1940).

7. J. H. Hollomon: "The Notched-Bar Impact Test," *Metals Technology,* AIME, vol. 11, No. 3, T.P. 1667, April, 1944.

Instrument Show Offers Measurement Courses

ARRANGEMENTS UNDERWAY for the first National Instrument Conference and Exhibit, sponsored by the Instrument Society of America, Pittsburgh, at the William Penn Hotel, of that city, Sept. 16-20, include plans for short courses at Carnegie Institute of Technology, Pittsburgh, according to announcement of Richard Rimbach, executive secretary of the society.

Courses, which will be under the direction of Dr. B. R. Teare, Jr., head of the school's electrical engineering department, will consist of five two-hour sessions. Subjects are: industrial instruments, machine shop measurement, optical measurement and electrical measurement.

Woman Awarded A.F.A. Veteran's Pin

MISS ETTA MOSES, for more than half a century a Stenographer (she has always preferred a capital "S") in the office of Griswold Manufacturing Co., Erie, Pa., has been presented with a 50-Year Pin by A.F.A. Secretary-Emeritus R. E. Kennedy.

When the first cast aluminum teakettles ever produced were delivered to the office of the late Matthew Griswold, Sr., president of

Etta Moses

the Griswold company, in the early '90's, Miss Moses boiled water in one of them in a demonstration, thus participating in the activities through which the firm entered the aluminum casting field.

A model of this teakettle was included among the exhibits at the recent Erie Foundry Exhibit, and Miss Moses and Mr. Griswold, Sr., were portrayed in the technicolor sound motion picture, "Unfinished Rainbows," presented at the Erie Foundry Exhibit.

Richard Rimbach (extreme right, front row), secretary, Instrument Society of America, meets with other members of local committee in charge to complete arrangements for "Instrumentation for Tomorrow" conference and exhibit to be held Sept. 16-20, at William Penn Hotel, Pittsburgh, Pa.

50 YEARS OF PROGRESS IN FOUNDRY

TIME AND METHODS STUDY

Harry Reitinger
The Emerson Engineers
New York

IN 1642, just 22 years after the Pilgrims had landed, a foundry was established on the banks of the Saugus River in New England and the first American-made castings were poured. The process then, before the invention of the cupola, was to pour the iron directly from the furnaces as it was reduced from the ore, with but little regard for or knowledge of the metallurgy involved. One of those early castings was a small tea kettle, which was exhibited at the World's Exposition in 1893 at Chicago to symbolize the immense foundry industry that since has become such a vital and basic element of our industrial economy.

Man-Hour Production

The total effort expended in making the small 2-lb. casting in those days of foundry pioneering, and the minute effort required per piece to produce in today's production-line foundry is visible evidence of the so vastly increased production per man-hour that has taken place during the industrial growing years of our nation.

From the period 1870 to 1940 the population of our country had increased three times, the number of hours spent per day in working had been reduced by one-third, and yet our production was increased over 20 times. This greatly accelerated increase in production has been the result of two dominant factors that are found in all advances made by civilization.

First, the increase due to technological discoveries, advances in newly developed processes and inventions, material discoveries, etc.; and second, the stimulated development of the individual worker to utilize his endowed capabilities of ingenuity and coordination to produce more with these newly developed tools and techniques of production.

Technological Factor

The technological factor is embodied in the science of design and invention, and has been used since the earliest days of history when an ingenious cave man engineer used a log as a wheel to decrease effort and increase production. The factor of worker production is found in the science of management, and it has been only in comparatively recent years that a concerted effort was made to stimulate individual production by efficient and effective management of men and the machines they operate.

With the advent of World War II the production demands upon our foundries and allied industries, coupled with the critical labor shortages, sharply focused attention upon increased worker output and efficiency as the only logical answer to a difficult production problem. The secrets of mass and efficient production, which had been thoroughly demonstrated in practice by Emerson and Taylor nearly 40 years earlier, were again called upon, for it was soon realized that only by increasing *efficiency* in production could we hope to deliver finished products at the accelerated tempo of production demands.

Application of proper wage incentives, to the end that increased production in the foundry will advance the industry and benefit all foundrymen, is one of the valuable lessons to be learned from recent wartime production experience.

Wage incentives were installed in foundries and other industries engaged in the war effort, and through the use of these incentive plans, and the cooperative effort of management and labor, it was possible to increase fourfold the monthly war production between December 1941 and December 1944, and at the same time deplete the industries of the best source of labor to build our Army and Navy. It was one of the most effective and certainly the least dramatized factor in our production battle at home.

Early Plans

Profit Sharing. The history of the wage incentive plans that have been used in foundries begins with the profit sharing systems established in the 1880's at the more progressive foundries and mills. Some evidence exists that these attempts at production increases were used earlier in the industry during the period of the territorial expansion into the West. Pillsbury Mills Foundries established excellent labor relations reative to wage payment, and made an early effort to capture the inherent extra production that lay dormant in the foundryman working on the day rate

Incentives mean higher wages . . .

by declaring a profit sharing plan in effect, whereby the worker would share in the earnings of the company and be thus stimulated to produce more.

At a foundry in Dolgeville, N. Y., the profit sharing system in effect created favorable comment at the time and resulted, in 1892, in a profit sharing bonus of 16½ per cent of the total wages earned that year. However, these seemingly ideal conditions were far from prevalent, and the plan was not generally adopted by foundrymen as the answer to the wage-production equation.

This same type of plan has recently been advocated by a prominent member of the United States Chamber of Commerce as a solution to present day labor difficulties, although it is doubtful if this is based upon an incentive motive. However, it is to be noted that the profit sharing system in itself failed to create the immediate production stimulus of other incentive plans that were to follow, and was not received with enthusiasm by employers during this early period of development.

Ten-Hour Day

By far the majority of the foundries at the close of the century were paying wages at a day rate to the employee working 10 hours a day, and depended entirely upon the efforts of the foundry foreman to obtain a day's production from the employee so that management would realize a profit from its investment in the foundry.

The foreman then was the key man on the floor and, as is often true in poorly managed foundries of today, was required to perform the multiple functions of hiring, discipline, instruction, scheduling, inspection, planning, and ordering, with the inevitable result of having little or no time available for the proper function of maintaining maximum production and quality. Then, as now, the basic issue at hand was the question, "What constitutes a day's work?"

An answer that appeared in an early issue of a foundryman's trade journal reflects the thinking of the times in matters of measured output per employee, ". . . but broadly speaking, when a man has worked hard and faithfully for a period of 10 hours, applying his mind to the task at hand, with an honest intention, he has done a fair day's work." The answer was vague and of little comfort to either the foundry management or the molder, and yet the same condition can be found in many of our foundries the country over.

Early Advances

Piece Rates. The latent possibilities of labor production and labor efficiency, however, lay dormant in the minds of management and labor and was not to be stirred into activity until after the turn of the century.

A small group of foundrymen, speaking some eight or nine years before their time in the industry, and touching upon the current teachings of Emerson and Taylor, lamented the fact that a poor worker was paid as much as a good one, and urged the molder's unions to reconsider their policies and encourage the use of premiums and bonuses as a reward to the efficient molder.

In a limited number of foundries by 1900 a successfully adopted piece rate system based upon sound engineering and management principles was installed and worked in a manner satisfactory to all concerned. However, the practice was unusual for the foundry industry at that date, but marks a step forward to the present day high production-low cost incentive plan. John Magee, a progressive and highly respected foundryman from Chelsea, Mass., in an early foundryman's magazine of 1904, wrote:

". . . It is first necessary to have a basis for prices that is beyond all dispute. This is secured by a contract, in duplicate, giving the molding price of each casting made, one copy signed by the molder's union and one by the firm. New work is priced before going into the shop. Wages are subject to a percentage increase or decrease in the case of a general change throughout the industry. The price may be changed by a new method or equipment change, subject to approval by both sides."

Good Faith Prevailed

For that period of wage development in the foundry industry, the plan was excellently designed and leaned heavily upon the current industrial management policies advocated by leaders in the field. It is evident that the absolute requirement of good faith prevailed between both members in the agreement, and that adequate employee education and preparation has been made before and during the operation of the payment plan.

That fundamental concept is one of the basic elements in the successful adoption of the modern wage incentive plan today and, to a large degree, is responsible for the smooth operation characteristic of the well engineered incentive plan.

Labor Difficulties in Wage Plans. This basic honesty between labor and management, total fair play regarding wage rates and adjustments, was by no means prevalent during the 1900's, and the workmen's apprehension and fear of premium and piece rate work was well founded in a number of instances, for the practice of rate cutting was common.

An ambitious foundry manager, working with more energy than common sense, would seize upon the first opportunity to cut manufacturing costs by reducing piece rates or lowering the premium. The inevitable repercussions would follow. Incentive pay systems suffered from the lack of established standards in the foundry, and were ill thought of by labor unions even though they often meant more pay for the employee.

Prevailing fear of rate cutting and standards set too high, together with the objection to sharing the time saved with the company, resulted in a strike which was called early in 1904 at a large Cleveland foundry. The plant announced that the employees would be placed on a premium system of payment in which they would share the time saved on a job on a 50-50 basis with the

company. The molders objected to the percentage of the time saved that they would receive, and stated that they were entitled to much more than 50 per cent.

Reduced Overhead

Need for pay beyond the 50 per cent point of time saved was recognized by Harrington Emerson before the turn of the century, when he advocated payment of labor for all of the time saved on a job and pointed out that management saved as much, or more, in reduced overhead expense. Where this plan of cooperation was followed, the plants operated smoothly and with mutual benefit to both partners of the production formula.

A solution to the difficult problem had been found, but the lessons of scientific wage administration and management in foundries and allied industries were destined to be learned by labor and management only after bitter strife and defeat during the years that followed.

Types of Incentive Plans Used. A brief description of the prevailing incentive plans for wage payment used in the industry from 1880 until World War I is indicative of the numerous and varied attempts to arrive at a satisfactory answer to the age-old problem of how to increase production of the individual worker and yet retain the peace and harmony that is needed in every enterprise for efficient production.

Premium System. In its various forms, this system was used in all types of foundries and in all departments, including the finishing room. The basic principle followed in all premium plans was to encourage the worker to perform a job in less time than the sometimes questionably established standard time allowed. The time saved was then distributed between the worker and the firm, usually on a 50-50 basis.

It was, in a sense, a negative plan for it encouraged the worker to work more efficiently and then penalized him by deducting half of the extra earnings. If, for example, molders were paid at the customary rate of 30c an hour and were allowed 10 hours to make a mold, but by working harder made it in 8 hours, the following benefits would be obtained:

Standard labor cost of mold: 10×30c=$3.00 for 10 hours	
Actual labor cost:	8×30c=$2.40
Plus ½ of time saved:	1×30c= .30
For 8 hours	$2.70

Hourly earnings of the worker are seen to have risen from 30c to 33.7c, and management has doubly benefited by a reduced labor charge for the mold in addition to the reduction in overhead. This double benefit of management was the center point of wage difficulties of the past and present times.

While this type of plan was successful in a limited number of instances, the poorly established standards usually associated with the premium plan, combined with the low rate of pay, soon generated discontent and other types of wage payment plans were adopted.

Higher Prices

Differential Rate System. With this system, higher prices per piece were paid if the work was done in the shortest possible time without error. It was a plan that induced strong incentive for increased production, but usually failed to offer compensation for faults beyond the molder's control. It lacked the inherent stability and guarantee for base wages that the modern incentive plan offers, and was, in time, replaced by more suitable plans. Comparative earnings under the plan are as follows:

No. of Molds Good	*No. of Molds Spoiled*	*Price Per Mold*	*Earnings Per Day*	*Earnings Per Hour*
10	0	20c	$2.00	20c
15	2	22c	2.86	28.6c
15	0	24c	3.60	36c

Gain Sharing. This plan was based upon the distribution of the financial gain made in a department. The gain in lowered maintenance, for example, was distributed among the maintenance foreman and his men. The reduction in the operation of the coreroom would be distributed among the coreroom foreman and the coremakers. The gain usually was divided in accordance with wages earned and failed to establish an adequate incentive motive for higher production.

Contract System. This system centered about the man selected for accepting the contract. He hired his own men and conducted the business that he had contracted for to his own satisfaction in accordance with the contract. The application of the system in the foundry usually was in the machine shop and the finishing room, and did not find extensive use on the molding floor.

Cooperative System. Under this system, prices were established much as in the other currently used plans but these rates were not used directly in paying. The foundryman worked instead, by the day, and from his wages and the number of pieces produced was calculated the actual cost of the core, mold, or casting. The difference between the actual and estimated price was divided between employer and employee. The plan lacked the immediate personal incentive that is needed for high production, and hence found application only in a limited number of foundries.

Participation Plan. This plan divided the gain in the lowered cost of manufacturing among the foremen in proportion to the payroll of each department. The foreman was then left to his own system of rewards among his men.

Profit Sharing Plan. Another form of the participation plan and among

. . . and lower production costs.

the first to be used in the industry, and is still being used with a questionable degree of success. The profit sharing plans inherently lack the immediate incentive stimulus of the modern type of incentive plan, and have repeatedly failed in the effort to increase production by this means.

Profit Sharing

One of the basic fallacies in using profit sharing as a production incentive is that the reward usually is made once or twice a year instead of immediately after the bonus work has been completed, hence losing the psychological benefit of immediate reward inherent in the modern, well adjusted incentive plan. If Junior knows that he will receive a quarter as *soon* as he finishes raking the leaves satisfactorily, he will be much more enthusiastic in his work than he will be if he knows that the quarter will be forthcoming at Christmas time.

This fact has been recognized in the plan designed for today's use, and the importance of the extra bonus is visibly presented to the worker in the form of an extra pay envelope of a different color. At each pay period he is thus reminded of the amount of extra pay he has earned because he was more efficient.

If the plan is simple, as it should be, the worker figures his bonus at the end of each day and knows just how much he has been rewarded for his efforts of the day. It is an idea that has been thoroughly demonstrated.

Wage Plans of Emerson, Taylor, Halsey, and Rowan were introduced toward the latter part of the last century and found numerous applications in the foundry industry. Since time study and scientific rate setting was in its infancy, some of the early users favored a plan whereby estimated base rates could be used and yet provide an adequate incentive for production. The Rowan plan limited the earnings to below 200 per cent so that the easily worked mis-rated jobs would not result in too much pay.

Taylor stressed the importance of the exact location at which bonus would begin and set the standards of performance before bonus would begin at a high rate. The plan was designed for the repetitive process industry but was of little use in the jobbing foundry because of the exact time standards at which bonus would begin.

Halsey's plan was a variation of the prevailing 50-50 premium plan with the guaranteed day wage incorporated in the plan. It was used in a limited number of foundries after 1900, but the basic objections to the premium plan remained.

The Emerson plan, using scientific time studied standards in a way that required but a few to be performed, was readily adaptable to the jobbing foundry and has since been adopted, in a modified form, in a number of foundries throughout the country. In the original Emerson plan of the 1900 period, the bonus was begun gradually and was made larger as the molder produced more and, consequently, the inducement to produce still more was created within the worker.

In direct contradiction to the prevailing plans being advocated, Mr. Emerson stressed the important fact that the worker was entitled to full hourly pay for the time saved, and that management would benefit equally as well from the reduced overhead as well as a reduced labor cost per piece. It was a long step forward in the solution of the wage-production problem.

Wage Difficulties of the Expanding Industry. The various plans were each with their own merit in their field of application and served well to explore the employee-employer relationship which, by 1905-1908, was being thoroughly investigated by both management and labor. Then, as now, the equating factor was an increase in wages only for a corresponding increase in production. The population of the country had risen from 50 million in 1880 to 63 in 1890, 76 in 1900, and was well on its way to 92 million by 1910. It was a time of national expansion and industrial growth, and the growing pains of industry were evident.

Labor Relations

The turn of the century had shown the world America's immense industrial growth, and, in like manner, brought forth the sharp and complex problems of labor relations that were upon us. The timely teachings of Harrington Emerson and Frederick Taylor focused the attention of industrialists upon management from a scientific point of view.

They held forth with the teachings then, 50 years ago, upon which our present day world leadership in production is based. They demonstrated with keen scientific analysis the prospects of operating plants in the most efficient manner, using time studies, standards of performance, production controls of material, men and machines.

Emerson's Advocations

Mr. Emerson advocated high wages and efficient production long before the time of Henry Ford, and delved into the prodigious and seemingly fantastic wasted efforts in men and materials of our industrial economy. His book, *Efficiency,* made its appearance in 1908 and was among the first of those that were to appear on the subject of wasted effort in manufacture in both manpower and materials.

In a lecture in 1908, before the American Foundrymen's Association, he stressed facts which remain fundamental truths of the foundry industry today.

". . . If, in the operation of a foundry, any dollars are spent needlessly, the loss is a foundry waste. Wastes of this kind are very common and easily overlooked. If a founder could forget for a few days all about iron and molding, and go through his own foundry with the same keen, alert, and awakened critical attention that the stranger who is not a founder sometimes displays, he could add unexpectedly to his profits and pleasure in the business. We had occasion recently to compare two foundries in the Middle West, each ranking high in the industry. One foundry produced castings for $1.40 per 100 pounds and the other $3.00 per 100 pounds. The labor costs were found to be only one-third as much in one as in the other, not because the men did not work hard, but because in one they worked less efficiently than in the other. In one foundry only one man was required per truck to charge the cupola, and in the other the prevailing arrangement required three men to do the same kind of work. In another foundry a piece rate system was installed. The men decided to curtail their output, some by working with fatiguing deliberateness, others would work fast for a while then dawdle or smoke to use up the remaining time. The plan used was not properly installed or administered and production costs rose instead of dropping.

"Every worker naturally wants, and ought to have, the highest rate of pay which circumstances will permit him to exact. On a very large scale a solution of labor compensation has been tried and operates with complete success. The men receive, in any case, a standard day rate of pay. A standard of fair cost was placed on every item of output, the output being what a good man working without undue strain could deliver in a day. If the out-

put were reached during a monthly average, the man was rated as 100 per cent and received a bonus. This was virtually a stipend for acting as his own foreman in maintaining maximum production. If the worker did better, all of the gain in time was his own. If he did less, he was still certain of his base pay. It is nonsense to pretend that in any plant the good man is not differentiated from the poor one, and since this is the case, it is absurd not to recognize the fact scientifically and fairly. The reward of efficiency merely gives to the worker that part to which he is entitled. He leaves to management the gains due to lessened equipment charges and overhead. With a system of this kind the net profits of a plant have increased several hundred per cent.

"An old foundry which eliminates waste will often find itself able to compete successfully with the larger more modern foundries. It costs very little to eliminate most of the wastes that occur."*

Although these advanced methods and techniques in human engineering and scientific industrial management had been evolved and thoroughly demonstrated by the leaders in the field, the accepted practice in the foundry industry was to retain the day rate as the method of wage payment. The profit sharing plans were still being used with some questionable measure of success.

Opposition

Opposition to profit sharing and the bonus system made the work of farsighted managers difficult. The general attitude of mistrust still prevailed and proves the fundamental concept in wage payment administration that honesty between labor and management must obtain if desired results are to be gained and retained.

World War I Stimulus to Incentive Plans. With the advent of the first World War in Europe, the attitude of "preparedness" swept the country and was used in American industry as the word "emergency" was used before our entry into World War II. Several papers were written and presented before the American Foundrymen's Association discussing ways and methods of improvement by using labor's potentialities of increasing and newer techniques of production.

Borrowing from the teachings of the early leaders, two foundrymen* from Urbana, Ill., designed a high production molder's bench and demonstrated the merits of the invention at the 1914 A.F.A. Convention. The bench was designed to eliminate wasted motion and increase worker production. The flask was set at the proper height and in the correct relative location for working.

Tools were within easy reach and eliminated many of the usual hunting motions for the proper slick or lifter familiar to the foundryman. The strike-off bar was placed conveniently in front of the flask, and the riddle was located in the most convenient place.

The net result was to cut the time for making a mold from 5.34 to 3.83 min., a reduction of 1.51 min., or 28 per cent per flask. The important fact to note was that the molder was working more efficiently but not nearly as strenuously and produced, as a result of his more efficient work, 39 per cent more in a given time.

Many similar economies are possible in the foundries of today merely by using motion studies in selecting the proper method to be used, and then utilizing a sound incentive system of pay to obtain maximum production with this proper method. This plan is being used repeatedly in the high production-low cost foundries throughout the country.

One of the more difficult applications of foundry incentive pay is in the cleaning and finishing room of a jobbing foundry where all types and sizes of castings are to be found. One of the earlier plans adopted by one of the more progressive foundries of 1915 was based upon their own incentive system which had been in operation in the molding department for several years.

Labor in the cleaning room was foreign born and it was felt, with a justifiable sense of apprehension, that the cleaning room force would react unfavorably toward the new incentive plan because they failed to understand it. This is overcome in the modern incentive plan by proper employee education before and during the installation of the plan. However, in this plant, the reputation of the highly paid molder had spread and the cleaning room force was willing and cooperative.

Work was divided into the five classes of sawing, sand blasting, sledge work and cold cut, grinding, and air hammer work. The basis for setting rates was the logical one of weight for most of the work. Since standards times were to be estimated by the foreman quickly and without a scientific means, they were subject to considerable error.

Premium Plan

It was decided to add 100 per cent to the actual time estimated to perform the task, and this would serve as the standard time at which the man was to do the work. The worker would then receive 25 per cent of the extra time saved and 75 per cent would go to the firm. It was the premium plan again, in a different form but with the same disadvantages of vulnerability to change in rates if the foreman decided to be economical and reduced the estimated standard times.

Although the plan was not comparable to the present day plan, it produced results and increased output to a limited extent. The change in attitude of workers is reflected by the fact that the men used sledges 3 lb. heavier after the plan was installed, whereas formerly it was necessary to discharge some laborers for grinding the sledges on an emery wheel.

At the close of the first war the efforts of the foundry industry and labor to arrive at a satisfactory conclusion for production were centered about the bonus system and piece work as the prevailing satisfactory answer. The record for premium plans in foundries had worked out quite decisively against them, and the efforts of profit sharing were found to lack the incentive motive when applied to large groups.

Companies using incentive plans steadily increased in number and, where the plans were soundly engineered and administered, excellent

*The author had occasion recently to visit an old and well-worn foundry and found that the statements mentioned in the 1908 talk are still true in every respect. The foundry could easily have been rehabilitated industrially and, with proper methods of operation and wage incentives for production, could have outproduced its competitors and been in excellent condition for the post-war period of competitive production. This production change could have been made without purchasing new equipment but, instead, would have utilized existing equipment to its utmost efficiency. It is a well-known fact that many plants producing in 1946 are using methods of production and management that were outmoded in the progressive plants of 1900.

*R. E. Kennedy and J. C. Pendleton, "Elimination of Waste Motion in Bench Molding," TRANSACTIONS, American Foundrymen's Association, vol. 23, pp. 311-322 (1914).

results were obtained. The incentive plan that was installed in a Western jobbing foundry employing 375 men is still being used after 22 years of profitable success. It is representative of the success that a well engineered plan will render.

Wage Changes During the Depression. During the years immediately following 1929, the entire wage structure of American industry underwent a tremendous change. Large labor organizations were formed in place of the smaller company unions. Wages were increased and hours of work were reduced below the 1929 level, necessitating a large increase in production to offset the effects of the change.

Unfortunate publicity and confusion toward incentive plans resulted with the "speed-up" methods of the moving assembly line. Gang incentive rates in the mass-producing automotive foundries were replaced in a number of places by a day rate with the production incentive being derived from the moving-assembly-line method of making and pouring molds.

Incentive Plans Increase

However, throughout the years, the number of wage incentive plans in foundries continued to increase and were greatly accelerated by the heavy production demands of the war.

A need for incentive plans and improved methods and techniques of production still exists in most foundries today where the piece rate is used, and the incentive plan can be used to still greater advantage in the day-rate foundry where the incentive stimulus is lacking.

In the days of keen competition that lie ahead, the foundries that will retain their business and continue to expand are the progressive ones with, not necessarily the most modern equipment, but the most modern and efficient management to utilize the existing equipment to the maximum efficiency possible to produce quality castings at a minimum price.

Modern Foundry Wage Incentive Plan. The heart of a sound wage incentive plan is in its ability to increase production at a lowered cost and with complete satisfaction to both labor and management. That in itself sounds like a big production order, and yet it is the basis of the well managed foundry of today and will be a deciding factor in obtaining a share of the work to be done tomorrow.

One of the most successful plans in operation today is, as might reasonably be expected, one that is the least complex in its operation and structure. The plan is based upon the unchanging unit of "standard time," which means, in effect, that the bonus automatically fluctuates with the rise and fall in the base hourly pay.

Finding Efficiency

Efficiency of the worker is found by the simple calculation of dividing the standard time by the time the worker actually took to make the mold, or core, or other item of production. By means of this efficiency, based upon the common unit of time, accurate comparisons between departments are possible, and serve well in indicating to management where a possible source of trouble may lie.

Efficiency can be calculated each week or every two weeks, as the pay period may be, and thus eliminate the cumbersome bookkeeping of figuring the actual working earnings of the employee each day.

The bonus, in keeping with the original Emerson theory of high wages for high production, begins when the worker has done 80 per cent of the work that the standard time calls for and increases one per cent for each increase in production of one per cent. Thus it is seen that the worker reaches bonus pay comparatively early and is thus stimulated to produce as much more as he possibly can in the remaining time.

Competition

He competes with himself and knows that all of the time he saves is his own. It is a strong incentive for increased production and works well in every case. If, for example, the molder does exactly a measured day's work, or is 100 per cent efficient, he has already received a 20 per cent bonus. If he had done work at 120 per cent efficiency, he receives a 40 per cent bonus for its successful completion.

Easily Understood

The plan is easily understood by everyone and the men usually calculate their own bonus on their way home from work. They know at the end of each day's work just how much more they have received for the extra production they have done.

Immediate production cost effect of this increase in production is best demonstrated by an example. Let us assume that the molder is paid at the rate of $1.00 an hour, works 8 hours a day, overhead charges are at the rate of $1.00 an hour, and the average day production is eight pieces.

A glance at the following table indicates that production increases by using this plan of payment result in hourly earnings rising steadily, labor costs and overhead costs per piece dropping at a similar steady rate.

No. of Molds Made in Day	*Employee Efficiency, per cent*	*Hourly Pay*	*Labor per Mold*	*Overhead per Mold*	*Total Cost per Mold*
6.4	80	$1.00	$1.250	$1.250	$2.50
8.0	100	1.20	1.200	1.000	2.20
9.6	120	1.40	1.166	0.833	2.00

Benefits to management as production increases are obvious and, since the two big cost factors in production are labor costs and overhead charges, a plan which effectively reduces these two simultaneously should be thoroughly investigated by every foundry manager in his search for reduced operating costs and increased income.

The standard time for doing work is arrived at in each case only after carefully considering all pertinent factors involved. "Gravy" jobs are eliminated and the stage is set for high production based upon fair standards. The workman now becomes, in effect, his own foreman, and will be the first to raise an objection if something interferes with his production rate, such as lack of material, working equipment, failure to issue a job order, etc. His interest now will be the same as that of management and they will have met on common ground—increased production.

WEIGHT OF CLAY BINDERS

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IN A PAPER by E. E. Woodliff*, in which the advantages and disadvantages of different types of binders are discussed, the author gives the weight of these binders per volume and weight measure.

Fire clay is given as 2.4 lb. per qt., and bentonite as 1.8 lb. per qt.

Although many realize that the two may not show the same weight per qt., the extent of the difference is not always realized. The degree to which the material is compacted in the container may also make a difference, depending upon whether it is dumped in loosely or shaken down.

In order to obtain some information on this subject the writer collected a number of samples of powdered clay from the producers. These samples were treated in two ways:

1. A specimen tube, such as is used for ramming a 2-in. specimen, was filled to the top and the excess struck off.

2. The tube was filled as before, and then set on a small metal table to which was attached a vibrator with a rate of 7200 vibrations per minute. This action, carried on for 30 sec. at maximum amplitude, caused some settling and compaction of the material. The tube was again filled to overflowing, vibrated for another 10 sec. and then struck off.

In both cases the contents of the tube were weighed, and from the known volume of the tube the weight per qt. was calculated.

All samples were dried in the oven before testing to free them from moisture.

The following interesting figures were supplied by Professor A. I. Andrews of the Department of Ceramic Engineering, University of Illinois, in a comparison of the bulk weight of dry bentonite and fire clay powder:

Bentonite, lb. per qt.	*Fire Clay, lb. per qt.*
2.25	2.82
2.44	3.00
2.53	
After Micro-Pulverize Operation	
1.30	2.59
1.31	2.92
1.67	2.99
1.75	
1.79	

The increasing numbers in each case, read downward, represent the increasing weight of each qt. after shaking the bottle so that the material became closer packed.

A consideration of these figures is not without interest. In many foundries the ingredients of a sand mixture are often measured out by volume.

Weight vs. Volume

When papers are published giving the ingredients of a mixture and describing their effects, the constituents sometimes are stated by weight and sometimes by volume. Let us see what difference this would make.

If to a 2000-lb. batch of sand is added 4 per cent of southern bentonite, this would be 85 lb., or 47.7 qt., according to the figures given previously. The same percentage weight of fire clay would require only 35.2 qt.

If a box large enough to hold 47 qt. (85 lb.) of southern bentonite were filled with fire clay, the weight would be 115 lb., which would be equivalent to about 5.43 per cent of fire clay in the mixture.

It is understandable that 5.43 per cent of fire clay would give a higher green compression strength than would 4 per cent.

The amount of moisture in the clay as received might also make a difference in the actual weight of the two clays. In this connection figures given by D. C. Williams* are of interest.

In a lot of 59 bags of western bentonite "as received" the weight in lb. per qt. as determined ranged from 1.52 to 1.91 lb., with an average of 1.65 lb.

The moisture in the bentonite "as received" varied from zero to 9.16 per cent.

If these figures are applied to the example given previously, where a box holding 47 qt. was used to add 4 per cent of bentonite to a foundry mixture, it is found that in using the bentonite "as received" it would amount to 89.8 lb. in one case, and 71.5 lb. in the other; or 4.33 per cent and 3.45 per cent, respectively, of bentonite.

Turning now to the dried samples of the 59 lots of bentonite, the weight per qt. ranged from 1.525 to 1.76 lb.

It is indicated that an increasing moisture content will tend to decrease the weight per qt.

In conclusion, it may be said that weight of clay per unit volume is a matter that should not be overlooked in making up foundry mixtures, for with a given clay the weight per unit volume may vary with the degree to which it is packed into a receptacle, with the degree of moisture in the clay, and with the fineness of grinding.

Furthermore, the variation in weight of unit volumes of different clays may be appreciable.

*A.F.A. Sand Research Fellow, Cornell University, Ithaca, N. Y.

*E. E. Woodliff, "Some Properties of Foundry Sand Binders," *Steel Foundry Facts*, no. 52, Nov., 1945.

*Material**	*Weight, lb. per qt.* — *Tube filled*	*Tube filled and vibrated*
Southern bentonite	1.7	2.03
Fire clay	2.41	2.91
Fire clay flour	2.9	3.46
White clay	1.96	2.3
Bond clay flour	2.8	3.32
Western bentonite—200 mesh	1.8	1.91
Western bentonite—250 mesh	0.88	0.913
North Carolina kaolin	1.27	1.44
Ball clay	1.98	2.04
Bond (refractory)	—	2.6

*Trade names of products used may be obtained form the author.

Back Issues Needed

In order to complete its AMERICAN FOUNDRYMAN file, the Library of Congress, Washington, D. C., must obtain copies of the following back issues:

Vol. 4, No. 7, July, 1942
Vol. 5, No. 3, March, 1943
Vol. 5, No. 6, June, 1943

Since the National Office is not in a position to supply these numbers, which have long been out of print, the Library's request is directed to the attention of our readers.

If you have available copies of any of the above issues, please forward them to: The Secretary, American Foundrymen's Association, 222 West Adams St., Chicago 6, Ill.

PRECISION CASTING PROCESS

Fig. 1 (above)—Preparation of injection dies.

Fig. 2 (left)—Diemaker preparing to pour metal into first half of mold.

Fig. 3 (below)—One-half of die completed, the plaster is removed and second half is poured.

PRECISION CASTING by the investment or lost wax process, as conducted at the plant of the Haynes Stellite Co., was viewed by editors and writers of a number of trade magazines during a recent two-day visit to the plant at Kokomo, Ind. This manufacturer, primarily, produces alloy castings having high hardness for cutting and resistance to abrasive wear, corrosion-resistant alloys, castings requiring resistance to scaling at elevated temperatures, and alloy castings having high strengths at elevated temperatures. Essentially, its products comprise various alloys of the cobalt- or nickel-base type, and stainless steel of varying composition to meet specific and exacting end requirements.

Casting operations may be divided into two categories: (1) large castings made by methods quite similar to those utilized in the steel foundry, and (2) small or precision castings made by the investment process. Because of the large amount of interest displayed in the latter process, this article will largely confine itself to a description of the methods utilized in this plant, together with a brief description of the type of casting to which these methods are applicable, some of its attributes and limitations, with typical examples of its application.

Making the Master Pattern. A precision casting begins with the making of a master pattern, an exact replica of the piece desired. Of necessity it is slightly oversize by approximately 1½ per cent to allow for shrinkage and such additional increase in given dimensions where stock is required for finishing, which usually is limited to grinding opera-

tions on the hard alloys, or machining operations on the corrosion-resistant alloys and stainless steel.

As in all patterns, allowances must be made for draft and the surface finish must be good, since imperfections in the pattern surface are reproduced in the finished casting. The master pattern is fabricated from brass, stainless steel, or other material, depending upon the design of the part. The master pattern, after careful checking against the specified dimensions, is utilized for the production of the injection dies.

Making Dies

Injection dies are made by imbedding a master pattern in plaster in order to make the top half of the die, as shown in Fig. 1. The injection die itself is prepared by pouring a suitable soft metal, usually a low-melting tin-bismuth alloy, around one-half of the master pattern as it is imbedded in the plaster. Thus the die becomes a negative counterpart of the master pattern, the cavities in the die being a duplicate of the master pattern. A die is similar to the core box of ordinary foundry practice.

Having completed one-half of the die, the second half is made in a similar manner. The advantages of the previously mentioned type of alloy are mainly its low melting temperature and its freedom from contraction on freezing. When the casting itself is extremely simple in shape, it is often expedient to machine the injection dies directly from aluminum or other suitable metal and thereby avoid the construction of the master pattern.

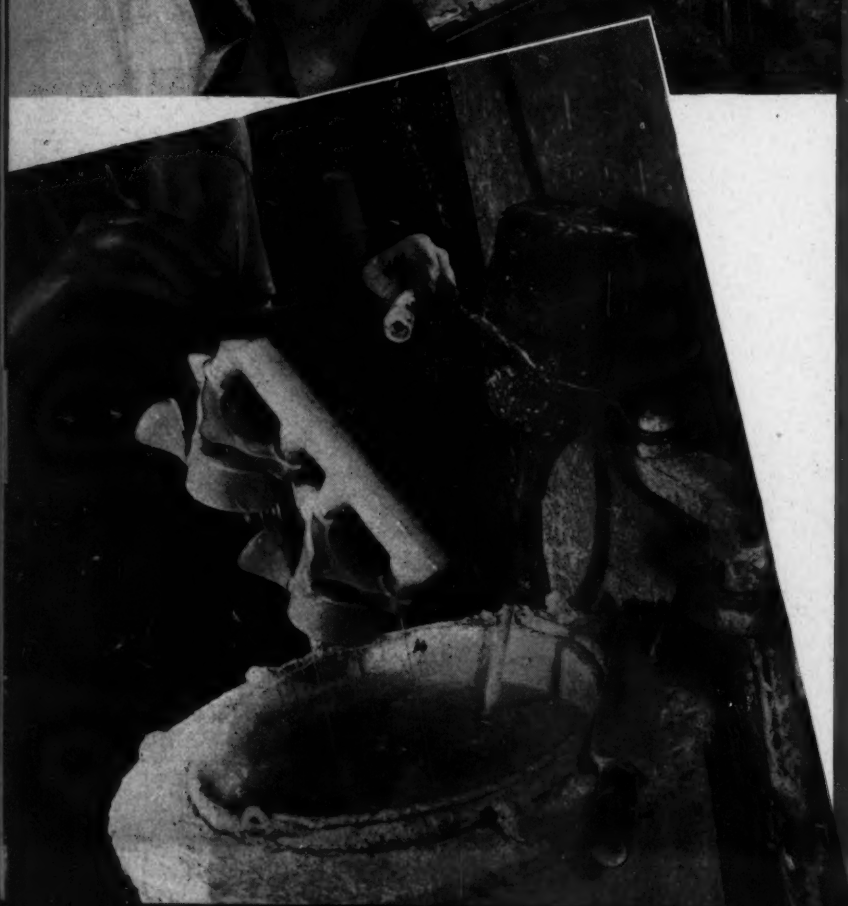
Pouring the first half of the mold for the production of the injection die is shown in Fig. 2. Both halves of the completed injection die are shown in Fig. 3. An injection die may contain from 1 to 20 cavities, depending upon the size of the part

Right—Reading from top to bottom:

Fig. 4—With required cores in die, wax is injected into mold by means of gun.

Fig. 5—Wax pattern being removed from mold.

Fig. 6—Inspection and assembly of patterns to wax gates and risers by "wax welding."



which is to be produced, since with more cavities each injection produces more wax patterns. For high production, it is desirable to get as many pieces into a given die as is practicable.

Pattern Wax. Wax utilized for making the wax patterns is a blend of several waxes compounded to produce a casting wax, which on injection into the die will accomplish dimensional reproducibility, good castability, sufficient strength and stiffness at the usual temperatures existing in the plant. It must also be free of impurities which will affect the other factors essential to the production of a suitable pattern and devoid of foreign material, which will effect consistent behavior of the wax.

Typical waxes utilized for compounding a pattern wax are: Beeswax, Carnauba wax, and several crystalline type petroleum waxes similar to paraffin. These waxes are accurately weighed and carefully melted to avoid volatilization of certain of their constituents, and then cast into slabs for future use in the wax pattern injection molding machines.

Wax Patterns. The beginning of the investment mold is the wax pattern which is a replica of the original master pattern. Wax patterns are made by injecting molten wax into the water cooled metal injection die. A gun containing the molten wax is inserted into the die opening and the wax forced into the die by a pneumatic ram under a pressure of about 400 psi. Temperature of the molten wax must be controlled to within 5° F. in order to attain the necessary uniformity.

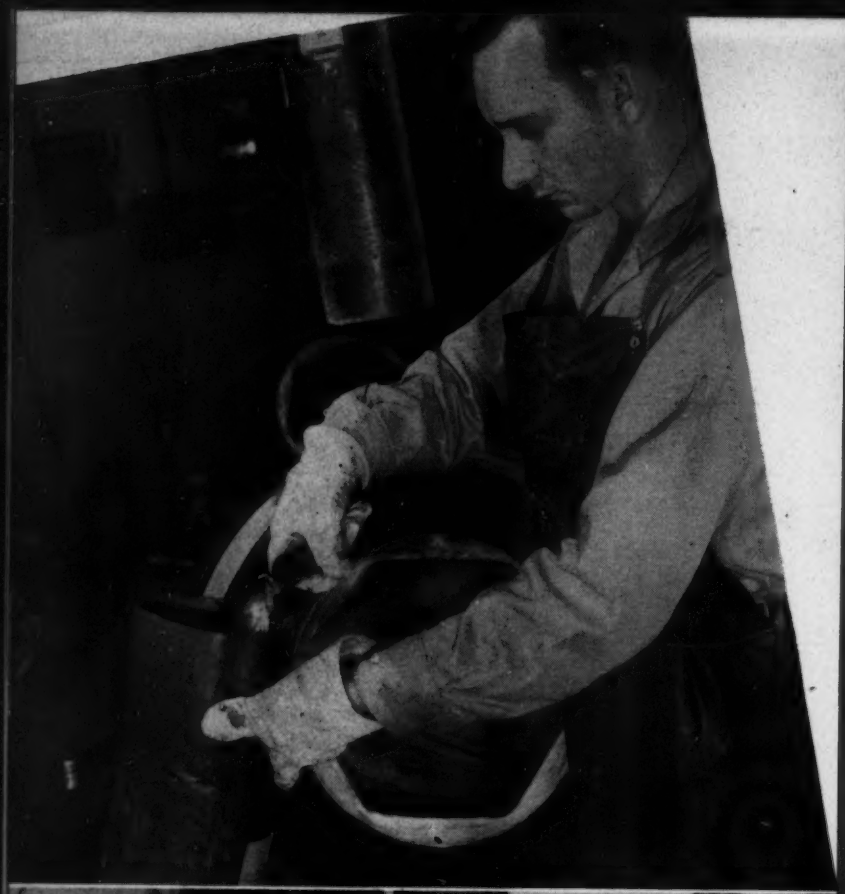
After a short interval of time, to permit the wax to solidify, the die is opened, special knock-out pins are operated to free the wax pattern, which is then removed by hand. This operation is clearly

Left — Reading from top to bottom:
Fig. 7—Attaching blind risers.
Fig. 8 — Mounting two wax patterns to main gate and runners.
Fig. 9 — Dipping pattern assembly into very fine silica suspended in suitable medium.

Fig. 10—Wax pattern mounted on steel plate and uncoated areas sprayed with silica.

Fig. 11—Coarser grains are screened onto wet dip coating.

Fig. 12—Alloy flask being sealed to steel plate and wax paper roll extension applied around flask.



shown in Figs. 4 and 5. When the wax pattern is removed from the die, any cores which were used are removed and the wax gate is broken off manually. The die is then sprayed with a soap solution to prevent sticking and is ready for another injection.

Wax Pattern Assembly. Each wax pattern is carefully trimmed and important dimensions checked by means of gauges or micrometer calipers. Several of the wax patterns are assembled by "wax welding," with the aid of a "hot-wire" welder, to appropriate gate and riser patterns cast in their own dies. The welder is simply a short piece of resistance wire heated by an electric current to a mild temperature that will melt the wax.

This assembly operation is conducted progressively by a number of operators as the component parts move along on the assembly conveyor belt, and is well portrayed in Figs. 6, 7, and 8. The practically completed wax pattern assembly is shown in Fig. 8, with the operator welding the gate assembly to the wax pattern.

Dip Coating the Pattern. Completely integrated pattern assemblies, after careful final inspection, are dipped in fine silica flour suspended in a suitable medium. The presence of the fine material on the wax is responsible for the smooth finish of the castings, since the wax is later melted out and this fine material forms the inside mold surface which will be in contact with the molten metal. The dipping operation is shown in Fig. 9.

After dipping, the pouring mouth of the wax assembly is sealed to a steel plate. Areas not coated by the dipping process are sprayed with the finely suspended silica, as shown in Fig. 10. While the dip coating is

Left — Reading from top to bottom:
Fig. 13 — Filling flask with chemically hardening investment material.
Fig. 14 — Molds on "shaker table" to pack investment around pattern.
Fig. 15 — Molds entering continuous furnace to melt out wax pattern and cure mold.

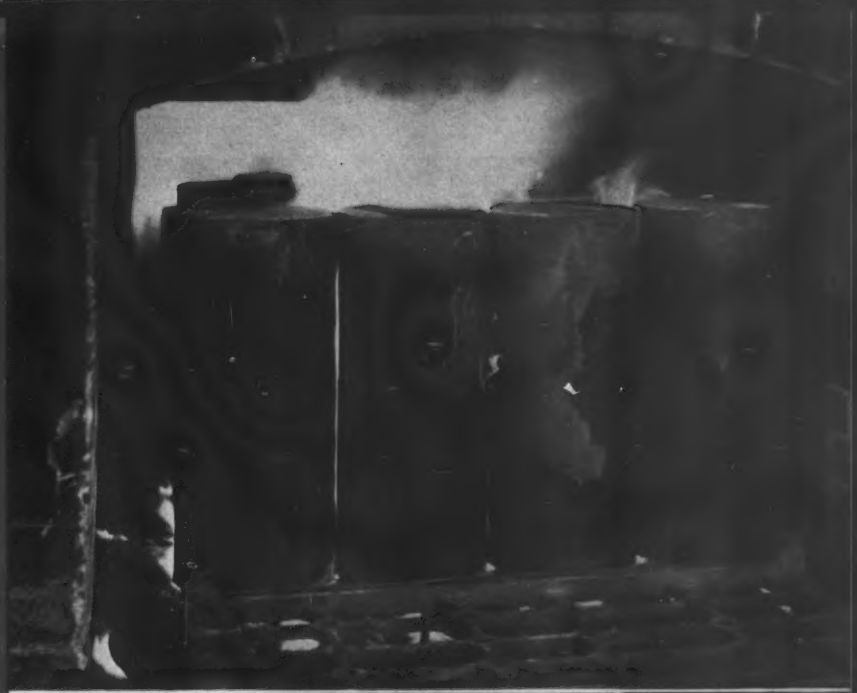
still wet, somewhat coarser dry silica is "screened" or "stuccoed" to the dip coating. This operation is shown in Fig. 11. The entire assembly is now placed on a conveyor and travels through a dehumidifying tunnel, reaching the exit end in approximately 22 min. Warm air circulated through the tunnel thoroughly dries the refractory coating on the wax pattern.

An alloy metal flask lined with wax paper is placed around the assembly and sealed with molten wax to make it liquid tight, as shown in Fig. 12. The flask is sealed in a wax paper roll that is longer than the flask, and serves to hold the surplus investment material later cut off.

Investment Material. Investment material must be a mixture lending itself to dimensional reproducibility, good flowability, so that it will completely fill the mold and conform with the fine detail in many small precision castings, possess ample permeability, strength at both room and the elevated temperature at which the mold is poured, and freedom from wash or cutting by the molten metal.

The mix, as poured into the flask, is a thick slurry prepared in an overhead room. Dry components, consisting of silica sand and flour, magnesia, and brick dust are first mixed in a rotary blender followed by mixing with the liquid constituents in a conventional concrete-type mixer. The liquid portion of the mix is a water solution of tetraethyl silicate, ethanol, hydrochloric acid and other chemicals.

After a second mixing of the slurry, it is ready to ladle into the flask containing the wax pattern, as shown in Fig. 13. Molds are inclined and slowly rotated to aid the flow of the slurry and eliminate large voids. Since the mixture sets



Right—Reading from top to bottom:
Fig. 16—Hot molds at discharge end of furnace ready to pour.
Fig. 17—Inverted mold clamped on furnace ready to pour by inverting.
Fig. 18—The shakeout. No attempt is made to salvage used investment material.

Fig. 19—X-raying the finished castings.

quickly, the flow of molds and investment material must be closely coordinated. Frequent cleaning of the mixing and handling equipment is also essential to prevent lumps of partially set investment from entering the mold and causing defects in the casting.

Both the tetraethyl silicate and ethanol are inflammable, necessitating care and forced ventilation to prevent fire in locations where the mixture is being compounded and handled.

Vibrating the Mold. Having filled the flask with the investment mix, it is placed on a vibrating table for about one hr. to pack the investment material around the wax pattern assembly and eliminate all air pockets (Fig. 14). The vibration also serves to settle some of the solids against the wax pattern and permit the liquid portion to jelly.

Following the vibrating period, the mold is permitted to age for not less than one hr. to attain sufficient green strength, after which the excess paper feeder or collar on the flask and investment is trimmed away, the mold board (steel plate) is knocked off, exposing the pouring mouth or dish into which the metal will ultimately be poured. The mold is now ready to be trucked to the foundry.

Melting Out the Wax Pattern and Curing the Mold. Just prior to pouring, the inverted mold is placed on the conveyor of a continuous zonal-controlled furnace (Fig. 15). Entering the first zone it is heated to a temperature at which the wax pattern is melted, most of it running out but some penetrating the aged investment to a depth of about one in.

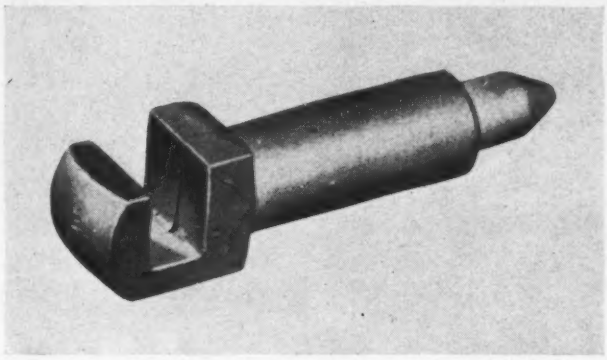
Moving then into hotter zones, the residual wax burns out and the mold finally is heated to temperatures of 1300-1900° F., serving to completely cure the investment and control the pouring temperature of the mold. Final temperatures are varied, depending upon the part to be cast. Figure 16 shows the discharge side of the furnace with the hot molds ready to be placed on the melting furnace for pouring.

Melting the Metal. Melting of the alloy metal is accomplished in specially designed single-phase indirect-arc furnaces, pictured in Fig. 17. The steel shell is lined with a rammed monolithic magnesia lining. The carbon electrodes project horizontally into the furnace, supported in a water-cooled holder through which the electrical energy is supplied. The electrode holders also serve as trunnions for rocking the furnace during melting and just prior to pouring to prevent segregation of elements in the metal charge.

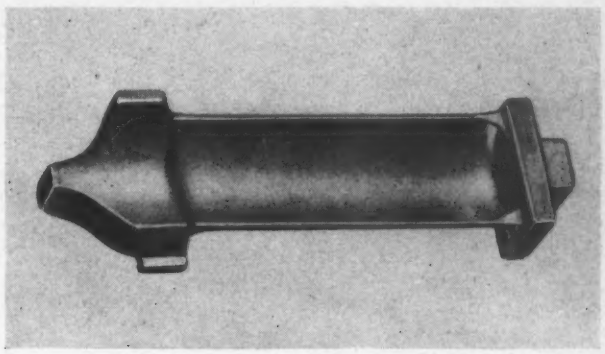
A metal charge consists of pre-alloyed material of the desired analysis, cast in rods of about ½-in. diameter. Charges weigh from 5-8 lb. and are introduced through a small hole in the roof of the furnace, which also serves as the pouring spout when a mold is poured. The weight of metal melted is governed by the quantity of metal required for a single mold. Depending upon the size of the charge, 6-12 min. are required to melt and superheat the metal to proper pouring temperature.

Under the existing melting conditions the metal sustains a carbon pickup of only 0.01-0.02 per cent and, since it is almost a sealed furnace, melting occurs in an inert atmosphere of nitrogen once the oxygen has been consumed. No slag is utilized, the metal being a bare bath. After measuring the metal

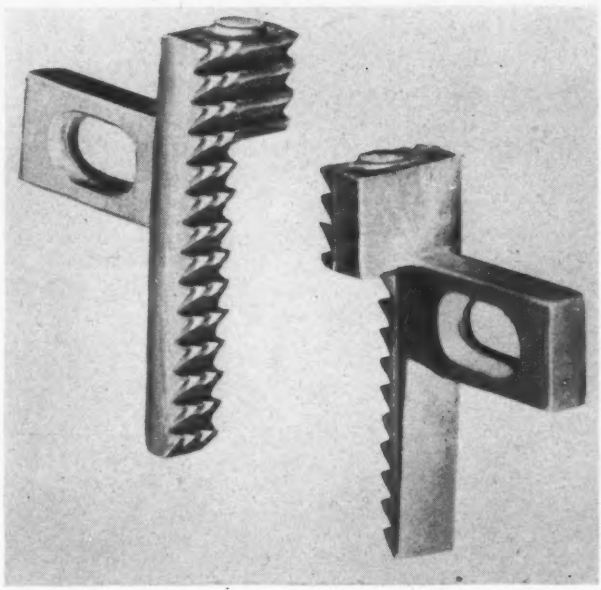
Fig. 20—Examining radiographs for casting imperfections.



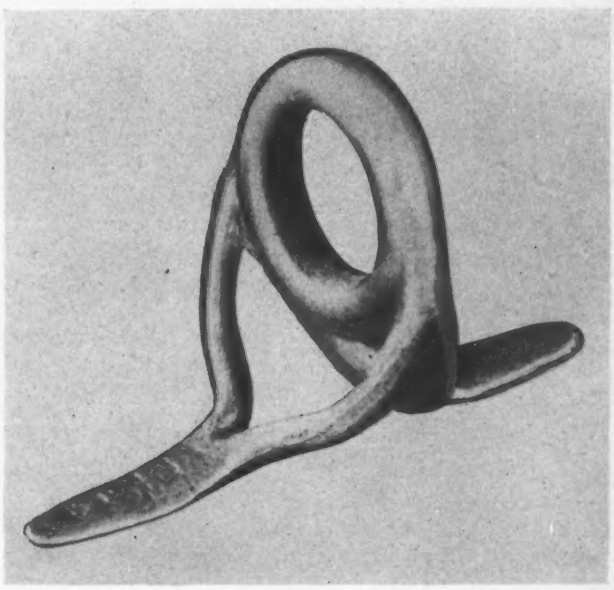
Valve part.



Turbo-supercharger bucket.



Sewing machine feed dogs.



Fishing pole guide.

Figs. 21-24—Typical parts cast by the investment process.

temperature with an optical pyrometer and placing an asbestos gasket around the pouring spout, a hot mold from the exit end of the mold-firing furnace is inverted, placed with the pouring dish over the furnace spout and clamped into place, as shown in Fig. 17.

The furnace is vigorously rocked by the operator, the entire assembly (furnace and mold) are inverted, permitting the molten metal to flow into the mold, and 3-6 psi. air pressure is admitted through the furnace shell by means of a cock. Regulation of the mold and pouring temperature are a means to controlling the desired grain size of the metal in the finished casting.

Utilization of compressed air during pouring assists in producing sound, dense castings, particularly those containing extremely thin sections or edges. After solidification, the clamp is loosened, the mold removed, and the furnace is ready for the next melt.

Knock-Out. Following the pouring operation, the mold is permitted to cool in air for about 4 hr. The entire casting assembly is then removed from the flask by means of a pneumatic hammer, shown in Fig. 18. No attempt is made to salvage the used investment material. The casting assembly is carried by conveyors to the cleaning room where the gates and risers are cut off with a high speed abrasive cut-off wheel and the casting shotblasted to remove adhering mold material. This is followed by rough inspection for obviously defective castings, which are scrapped at this stage of manufacture.

Cleaning and Inspecting. Castings accepted during rough inspection are sandblasted and returned to the inspection department for visual and dimensional inspection. Castings passing this inspection are examined with fluorescent penetrating oil and ultraviolet light for cracks or minute surface imperfections revealed by this method.

Since most alloys produced at this plant are non-magnetic, this type of inspection cannot be utilized. As a final check, all castings are x-rayed and the film inspected for evidence of defects in the castings, as shown in Figs. 19 and 20. Each casting is serially numbered and the corre-

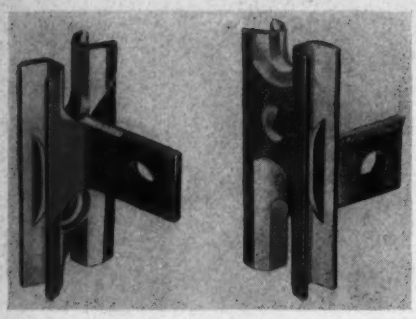


Fig. 25—Cloth cutting machine slide cast by this process.

sponding number applied to the x-ray film, which is filed as a permanent record.

When required, each mold assembly also contains a pattern for a Rockwell hardness test coupon, and two bend test specimens as a final check on the physical properties of the metal. Bend test specimens must bend through an angle of 90° without failure, and the hardness is maintained within narrow limits.

Application of the Process. This method of casting manufacture primarily lends itself to quantity production of small, simple or intricate parts cast so close-to-size that they require little or no subsequent machining. Dimensional tolerances usually are ± 0.005 in. per in., with a minimum of ± 0.003 in. Generally speaking, other factors remaining constant, dimensional tolerance is a percentage of the dimension involved rather than a fixed value.

Because of the relatively high molding cost, this technique lends itself to the production of small alloy parts which are too hard to machine, where precision molding will save a great deal of machining expense, where forming or forging is too difficult, or in instances in which accuracy of contour is highly important. Typical are heat resistant, accurately made, turbo-supercharger buckets, turbine blades, etc., which are made of alloys that are difficult to forge and of shapes which can not be economically machined or ground.

In a similar category are corrosion- and wear-resistant castings, such as parts for textile cutting machines, zipper slides, motion picture projector parts, canning machine components, parts for diesel engines, pulverizing equipment and various alloy items used in the chemical industry. Typical parts are shown in illustrations, Figs. 21 to 25.

Precision casting by the investment process is costly and requires extremely close and detailed process control of each operation if success is to be achieved. Briefly, this technique does not lend itself to adaptation by the average foundry; it is a highly specialized field of the casting industry.

Bibliography. For those who are further interested in the work which has already been published on investment casting, appended to this article is a complete bibliography covering this subject.

Bibliography

Albin, J., "Casting Cutting Tools from High Speed Steel Scrap," *The Iron Age,* March 1, 1945, vol. 155, no. 9, pp. 54-57.

Albin, J., "Equipment and Material for Precision Casting," *The Iron Age,* Nov. 9, 1944, vol. 154, no. 19, pp. 52-58; Nov. 16, 1944, vol. 154, no. 20, pp. 53-59.

Albin, J., "Industrial Precision Castings by a Manufacturing Jeweler," *The Iron Age,* Sept. 7, 1944, vol. 154, no. 10, pp. 73-77.

Anon., "Centrifugal Castings," *Canadian Metals and Metallurgical Industries,* Feb., 1944, vol. 7, no. 2, p. 40.

Anon., "Lost Wax at Work," *Scientific American,* Dec., 1945, vol. 173, pp. 334-336.

Anon., "Precision Castings," *Steel,* Jan. 10, 1944, vol. 114, no. 2, pp. 78-80, 82, 96.

Anon., "Precision Casting Process Saves Machining Operations," *Product Engineering,* May, 1944, vol. 15, no. 5, pp. 293-8.

Anon., "Tiny Precision Parts Now Cast Centrifugally," *Product Engineering,* Aug., 1943, vol. 14, no. 8, p. 481.

Birdsall, G. W., "Casting Supercharger Buckets at Allis Chalmers," *Steel,* Jan. 29, 1945, vol. 116, no. 5, pp. 72-75, 96, 99-100.

Cady, E. L., "Precision Investment Castings," *Materials and Methods,* March, 1946, vol. 23, pp. 742-760.

Clement, E. J., "Precision Casting of Metals," *Mill and Factory,* March, 1944, vol. 34, no. 3, pp. 98-100.

Ethyl Silicate. 12 pp. Published by Carbide and Carbon Chemicals Corporation, 30 East 42nd Street, New York 17, June, 1945.

Ethyl Silicate 40. 4 p. Information sheet published by Carbide and Carbon Chemicals Corporation, 30 East 42nd Street, New York 17, Feb., 1946.

Fisher, S. O., and George, E. E., "Precision Casting, Its Place in Design," *Machine Design,* Jan., 1945, vol. 17, pp. 123-126.

Focke, Arthur E., "Supercharger Buckets Mass Produced by Precision Casting," *Metal Progress,* Sept., 1945, vol. 48, no. 3, pp. 489-494.

Glaser, Jules W., "Refractory Molds for Precision Casting," *The Iron Age,* Feb. 8, 1945, vol. 155, no. 6, pp. 52-57.

Gott, Lester W., "Precision Casting of Low Alloy Steels," *The Iron Age,* June 21, 1945, vol. 155, no. 25, pp. 46-55.

Levinson, Benjamin L., "Industrial Precision Castings," *The Iron Age,* Oct. 26, 1944, vol. 154, no. 17, pp. 82, 156, 158.

Merrick, Albert W., "Precision Casting of Turbosupercharger Buckets," *The Iron Age,* Feb. 10, 1944, vol. 153, no. 6, pp. 52-58.

Neiman, R., "Precision Castings Employing Dental Technique by Investment Molding Process," American Foundryman, Sept. and Oct., 1944, vol. 6, no. 9, pp. 5-12; vol. 6, No. 10, pp. 7-15, and Transactions, American Foundrymen's Association, vol. 52, pp. 349-383 (1944).

Phair, W. A., "Precision Castings," *The Iron Age,* July 9, 1942, vol. 150, no. 2, pp. 39-41.

Post, Charles T., "Precision Casting With Plastic Patterns," *The Iron Age,* Nov. 15, 1945, vol. 156, no. 20, pp. 54-59.

Reeder, W. E., "War Producer Selects 'Lost Wax' Casting Process for Complicated Parts," *American Machinist,* March 2, 1944, vol. 88, no. 5, pp. 94-96.

Stubles, R. B., "Aircraft Manufacturing Technique Applied to Bus Building," *Machinery,* Dec., 1945, vol. 52, pp. 168-175.

Wolf, J. D., "Precision Casting for Ordnance and Aircraft," *Metals and Alloys,* Oct., 1943, vol. 18, no. 4, pp. 784-788.

Wolf, J. D., "Precision Castings for Ordnance and Aircraft," *Metallurgia,* Feb., 1944, vol. 29, no. 172, p. 226.

Wyman, L. L., and Basch, D., "Precision Castings," *The Foundry,* Feb., 1944, vol. 72, no. 2, pp. 116-117, 203-206.

Committee Plans Wider Chill Test Application

Reorganization of the Committee on Chill Tests, A.F.A. Gray Iron Division, under Chairman H. C. Winte, Worthington Pump & Machinery Corp., Buffalo, N. Y., was undertaken June 7, in a meeting at the Statler Hotel, Cleveland; and a program for the development of a series of chill tests applicable to the range of carbon equivalents found in industrial practice was adopted.

Development and standardization of the chill test, one of the most convenient quick tests, is expected to result from committee activities. More extensive application of the test was forecast.

H. H. Wilder, Eaton Mfg. Co., Vassar, Mich., was elected Vice-Chairman of the committee, and W. J. Sommer, Plainville Casting Co., Plainville, Conn., was named Secretary.

FOUNDRY PERSONALITIES

G. K. Dreher, National Director, American Foundrymen's Association, announces his resignation as vice-president and works manager, Ampco Metal, Inc., Milwaukee, to accept the position of vice-president and general manager, Rogers Pattern & Foundry Co., Los Angeles. Other officers of the Rogers firm, which has held A.F.A. company membership for a number of years, are A. E. Rogers, owner; Steven Mocsny, president, and G. B. Davis, superintendent, all active members of Southern California A.F.A. chapter.

G. P. Torrence

G. K. Dreher

W. C. Carter, president, Link-Belt Co., Chicago, has announced that **G. P. Torrence,** who resigned as president of the firm in 1936, will rejoin the organization as executive vice-president. With retirement of Mr. Carter, on Nov. 1, 1946, in accordance with the company's retirement plan, Mr. Torrence will again assume the presidency. Since his association with Link-Belt Co., from 1911 to 1936, Mr. Torrence has been vice-president and general manager, Rayon Machinery Corp., and president, Cleveland Pneumatic Tool Co., Cleveland.

At a special meeting of the Link-Belt Co. board of directors, at which arrangements were made for the return of Mr. Torrence, an executive committee was created, consisting of Mr. Carter, as chairman, and directors **Howard Coonley** and **Russell Livermore.**

C. M. Mense, president and general manager, Lehigh Safety Shoe Co., Allentown, Pa., announces retirement from active direction of the firm. Mr. Mense, who assumed the presidency in 1931, will continue in an advisory capacity. **F. B. Griswold,** who entered the organization in the sales department and trained through the merchandising and administrative departments, will replace Mr. Mense as general manager.

David White, executive vice-president, Lester Engineering Co., Cleveland, will fly to England for the firm, to confer with its British agents, Dowding and Doll, Ltd., London, and to license an English firm for the manufacture of Lester injection molding and die casting machines.

J. V. Houston has been appointed vice-president, Ramapo Ajax Div., American Brake Shoe Co., New York. Mr. Houston, who will make his headquarters in Chicago, is a graduate of the University of Illinois, Urbana, and joined the firm in 1910, serving since as sales engineer, sales manager, assistant chief engineer and general superintendent.

R. M. Reichl

J. D. Hanawalt

Erwin Loewy, president, Hydropress, Inc., New York, announces promotion of **Dr. R. M. Reichl** to the position of vice-president. Dr. Reichl, who obtained his degree as Doctor of Science from the University of Prague, Czechoslovakia, has been associated with the design, construction and operation of hydraulic presses and rolling mills for ferrous and non-ferrous industries in the United States, Europe, England and the Far East and has represented Hydropress, Inc., as consulting engineer in many new developments for the American armed forces.

H. J. Struebing and **P. J. Buchheit,** both formerly of Electro Refractories & Alloys Corp., Buffalo, N. Y., are principals, as president and vice-president, respectively, of Struebing & Buchheit, Inc., 1807 Elmwood Ave., Buffalo, a new firm of distributors of industrial products. Mr. Struebing was sales engineer for five years, and Mr. Buchheit assistant sales manager for nine years, with the Electro Refractories firm, prior to their resignations to form the new corporation. Both are active members of Western New York A.F.A. chapter, Mr. Struebing as a chapter Director.

Dr. W. H. Dow, president and general manager, The Dow Chemical Co., Midland, Mich., announces consolidation of the firms' magnesium operations under a separate executive board and general manager, and appointment of **Dr. J. D. Hanawalt,** former director of metallurgical research, to the position of general manager. Dr. Dow will serve as chairman of the new board, which will also include, in addition to Dr. Hanawalt, **G. F. Dressel,** formerly production manager, as assistant general manager; **Dr. T. H. McConica III,** formerly assistant technical manager and now technical assistant to the general manager; **H. Freuhauf,** former manager, Bay City, Mich., foundry and fabrication plant, who has been named production manager; **L. B. Grant,** who continues in the capacity of sales manager; and **C. E. Nelson,** former assistant technical director and advanced to technical director.

T. S. Hemenway, Metal & Alloy Specialties Co., Buffalo, N. Y., was elected president, Non-Ferrous Founders' Society, Chicago, at the annual meeting recently held in Cleveland. Mr. Hemeway had previously served as vice-president, and as a member of the executive com-

mittee and board of directors. E. W. Horlebein, Gibson & Kirk Co., Baltimore, Md., retiring president, remains as a director and was re-elected to the executive committee. Mr. Horlebein, an A.F.A. National Director, stressed the healthy progress made by the Non-Ferrous society, as he presented his annual report.

J. L. Klein has been appointed director of research, Jessop Steel Co., Washington, Pa. Graduate of Massachusetts Institute of Technology, Cambridge, Mass., Mr. Klein joined the Jessop firm in 1943 as metallurgical research engineer, and became head research metallurgist in 1944.

J. M. Underwood **Russell Franks**

J. M. Underwood, recently associated with Latrobe Electric Steel Co., Cleveland, as director of market research and previously president, The Halund Co., Latrobe, Pa., has been elected president, Vulcan Mold & Iron Co., Latrobe, succeeding **E. R. Williams,** who has resigned, according to announcement of the board of directors of the Vulcan firm. Mr. Underwood had served, earlier, as assistant treasurer and assistant to the president of Vulcan Mold & Iron Co.

Russell Franks, chief metallurgist, Union Carbide & Carbon Research Laboratories, has been appointed to the technical service and development department, Electro Metallurgical Co., Pittsburgh, according to **S. M. Norwood,** president of the latter firm. Both companies are units of Union Carbide & Carbon Corp., New York. Mr. Franks, well known in metallurgical circles as an authority on stainless and heat-resistant steels and author of many papers on the subject of chromium alloy steels, has been associated with the Research Laboratories unit since his graduation from Virgina Polytechnic Institute, Blacksburg, Va., in 1921, with a Bachelor of Science degree in chemical engineering. He was appointed chief metallurgist in 1945.

J. D. James, formerly assistant foundry superintendent, Erie City Iron Works, Erie, Pa., has been appointed foundry superintendent, Cooper-Bessemer Corp., Grove City, Pa. Graduate in metallurgical engineering from Grove City College, Mr. James had been associated with Latrobe Electric Steel Co., Latrobe, Pa., before joining the Erie City firm in 1941. Recently elected Treasurer, Northwestern Pennsylvania A.F.A. chapter, he has also served as a Director of the group, and was active in its organization in 1945.

G. K. Tolford, foundry superintendent, and **J. S. Nordholt,** engineer, Webster Manufacturing, Inc., Tiffin, Ohio, have leased the foundry at Swanton, Ohio, formerly operated by A. D. Baker Co. The plant will be operated under the firm name, Swanton Gray Iron Foundry, and is expected to be in operation this month.

W. A. Hambley, works metallurgist, Allis-Chalmers Mfg. Co., Milwaukee, has resigned that position to accept appointment as general manager, Slinger Foundry Co., Slinger, Wis., and Falls Mfg. Co., Menomonee Falls, Wis. Mr. Hambley is well known to the industry as a member of the Steering and Executive commitees, A.F.A. Gray Iron Division, and as Chairman of that group's Committee on Analysis of Casting Defects.

W. A. Hambley **W. G. Ferrell**

W. G. Ferrell, superintendent of foundries, Auto Specialties Mfg. Co., St. Joseph, Mich., has been appointed general works superintendent, and placed in charge of operations of all divisions of the firm. Mr. Ferrell, well known to the foundry industry, participated in the recent Golden Jubilee Convention at Cleveland, and was author of the technical paper, *"Cores for Automotive Malleable Iron Castings,"* presented at the May 7 Malleable Foundry Practice session.

O. L. Voisard **F. J. Wood**

O. L. Voisard, general foreman, Robert Mitchell Co. Ltd., Montreal, Can., has been appointed foundry superintendent. Mr. Voisard has been an active member in Eastern Canada and Newfoundland A.F.A. chapter since its organization, in which he assisted.

F. J. Wood, formerly chief engineer, Industrial Div., Goodman Mfg. Co., Chicago, has joined Loewy Construction Co. Inc., New York, as chief engineer, Rolling Mill Division. Mr. Wood, with the Goodman company since 1936, had specialized in design of special equipment for ferrous and non-ferrous foundries. Following attendance at Carnegie Institute of Technology, Pittsburgh, Mr. Wood began his steel mill career with Pennsylvania Works, National Tube Co., of the same city in 1917, and following service in World War I, served as assistant chief engineer of that firm. Later he was associated as resident engineer with Crucible Steel Co., Pittsburgh; moved to Mesta Machine Co. as department engineer; and, in 1932, joined the Leningrad (U.S.S.R.) staff of Freyn Engineering. Returning to this country, he spent two years as special engineer, Brass Mill Div., Western Cartridge Co., Alton, Ill., before joining Goodman Mfg. Co.

J. R. Cudworth has been appointed dean, College of Engineering, University of Alabama, University.

★ NEW A. F. A. MEMBERS ★

(Covering the period from May 15 to June 15)

• The enrollment of twenty-seven A.F.A. chapters was increased by the addition of one or more new members during the past month. Below the names of the 120 new members are listed. Three chapters, namely, Central Illinois, Eastern Canada and Newfoundland and Ontario, contributed nine new men apiece. The list of foreign members continues to grow larger with the return of many overseas foundries to normal peace time operation.

Conversion—Personal to Company.

***Crossley Brothers Limited, Openshaw, Manchester, England. (T. H. Bower).**

BIRMINGHAM DISTRICT CHAPTER

J. E. Bowman, Johnson City Foundry & Machine Co., Johnson City, Tenn.
R. P. Dalton, Gen. Foreman, LeTourneau Co. of Georgia, Toccoa, Ga.
***Henderson Foundry & Machine Co., Hampton, Ga. (J. E. Morton, Jr., Prod. Engr.).**
Wm. R. Peak, Owner, W. R. Peak Service Shops, Oklahoma City, Okla.
Sam P. Phelps, American Cast Iron Pipe Co., Birmingham, Ala.
Bruce B. Piper, Owner, Refractory Supply Co., Birmingham, Ala.

CANTON DISTRICT CHAPTER

Kenneth S. Gay, East Akron Casting Co., Akron, Ohio.
Robert A. Williams, Special Engr., American Steel Foundries, Alliance, Ohio.

CENTRAL ILLINOIS CHAPTER

Roy Bale, Foreman, Shipping Dept., Peoria Malleable Castings Co., Peoria, Ill.
Thomas F. Connolly, Foreman, Caterpillar Tractor Co., Peoria, Ill.
Cyrus E. Crouch, Foreman, Caterpillar Tractor Co., Peoria, Ill.
Sig L. Johnson, Draftsman, Caterpillar Tractor Co., Peoria, Ill.
John C. Koteles, Inspector, Caterpillar Tractor Co., Peoria, Ill.
Raymond Lewis, Caterpillar Tractor Co., Peoria, Ill.
***Peoria Foundry Div., M. H. Detrick Co., Peoria, Ill. (A. M. Klawitter, Mgr.).**
Robert R. Randolph, Asst. Chief Insp., Caterpillar Tractor Co., Peoria, Ill.
U. S. Sullivan, Gen. Foreman, Caterpillar Tractor Co., Peoria Ill.

CENTRAL INDIANA CHAPTER

Wilfred M. Bucher, Chief Insp., Swayne Robinson & Co., Richmond, Ind.
Supply Officer, Naval Ordnance Plant, Indianapolis, Ind.

CENTRAL NEW YORK CHAPTER

***Hallstead Iron Foundry, Hallstead, Pa. (E. Kime).**

CHESAPEAKE CHAPTER

Hubert R. Beale, Molder, Norfolk Naval Shipyard, Portsmouth, Va.
Edgar F. Felder, Jr., Sales Engr., The Gibson & Kirk Co., Baltimore, Md.
Robert M. Rubush, Jr., Plant Metallurgist, Lynchburg Foundry Co., Radford, Va.
Lloyd B. Saville, Price Analyst, Office of Price Administration, Washington, D. C.
Samuel R. Spence, Molder, Norfolk Naval Shipyard, Portsmouth, Va.

CHICAGO CHAPTER

W. H. Ball, Mgr., Ball Brass & Aluminum Foundry, Auburn, Ind.
George J. Biddle, Illinois Clay Products Co., Chicago.
Donald L. Colwell, Dist. Mgr., National Smelting Co., Chicago.
Karol J. Jacobson, Griffin Wheel Co., Chicago.
Walter Krywokulsky, Asst. Met., International Harvester Co., Chicago.
Arthur A. Rudowicz, Apprentice, Howard Foundry Co., Chicago.

CINCINNATI DISTRICT CHAPTER

Gilmer Penick, Pres., Queen Co., Inc., Cincinnati, Ohio.

DETROIT CHAPTER

Edward J. Hasty, Sand Tech., Harry W. Dietert Co., Detroit.
Arthur C. Robillard, Fdry. Engr., Giffels & Vallet, Inc., Detroit.
Edwin Wrobel, Mt. Engr., Ford Motor Co., Dearborn, Mich.

*Company Members.

EASTERN CANADA & NEWFOUNDLAND CHAPTER

***Algoma Steel Corp. Ltd., Montreal, Que. (M. E. Lane, Dist. Sales Mgr.).**
Jean H. Archambault, Service Mgr., Lasalle Coke Co., Montreal, Que.
L. Bradley, Asst. Fdry. Supt., Canadian Ingersoll Rand Co. Ltd., Sherbrooke, Que.
Ernest Clark, Dominion Engineering Works, Lachine, Que.
Ed Cyr, Industrial Pattern & Foundry Works, Montreal, Que.
Gordon K. Eastwood, Met. Engr., Crane Ltd., Montreal, Que.
Herbert H. Fairfield, Met., Bureau of Mines, Ottawa, Ont.
George C. Jarvis, Ind'l. Salesman, Lasalle Coke Co., Montreal, Que.
J. S. Morse, Fdry. Engr., Canadian Ingersoll Rand Co. Ltd., Sherbrooke, Que.

METROPOLITAN CHAPTER

Russell A. Clapp., Jr., Pres., Engineering Products Corp., Bridgeport, Conn.
David Sigmond, Basic Appliance Co., Brooklyn.

MEXICO CITY CHAPTER

J. A. Carey, San Miguel 24, Goyoacan, Mexico, D. F.

MICHIANA CHAPTER

N. S. Bowsher, The N. P. Bowsher Co., South Bend, Ind.
Don P. Grafflin, The Toy Co., South Bend, Ind.

NORTHEASTERN OHIO CHAPTER

Lester D. Criswell, Cleveland Repr., Wellman Products Co., Cleveland.
Gilmond W. Hart, Personnel Dir., Lake City Malleable Co. Inc., Ashtabula, Ohio.
Bert R. Lanker, Res. Met., Farrell-Cheek Steel Co., Sandusky, Ohio.
S. Allen Nathanson, V. P., M. Cohen & Son Co., Cleveland.
Bailey I. Ozer, V. P., M. Cohen & Son Co., Cleveland.
Frank J. Sedlak, V. P., The Superior Brass Mfg. Co., Mansfield, Ohio.
A. V. Seifert, The Ohio Injector Co., Wadsworth, Ohio.
John A. Sharritts, Asst. Supt., Westinghouse Electric Corp., Cleveland.

NORTHERN CALIFORNIA CHAPTER

Ernest Boyuton, Foreman, Enterprise Engine & Foundry Co., San Francisco.
Ted Campbell, Molder, Enterprise Engine & Foundry Co., San Francisco.
Gene P. Fambrini, Coremaker, Enterprise Engine & Foundry Co., San Francisco.
Charles E. Rowe, Met. Asst., Mare Island Navy Yard, Mare Island, Calif.
Charles A. Willard, Supt., Kingwell Bros. Ltd., San Francisco.

NORTHWESTERN PENNSYLVANIA CHAPTER

John L. Frantz, Plant Engr., U. S. Radiator Corp., Detroit.
C. H. Gable, Plant Supt., U. S. Radiator Corp., Detroit.
J. Marcus Moarison, Pttn. Shop Fore., U. S. Radiator Corp., Detroit.
Stanley B. Trezenski, Fdry. Supt., U. S. Radiator Corp., Detroit.

ONTARIO CHAPTER

***Beatty Bros. (Spencer Div.) Ltd., Penetong, Ont. (A. T. Atkins).**
R. K. Brake, Owner, Alumaloy Castings Ltd., Toronto, Ont.
W. A. Butcher, Core Room Supt., Dominion Foundries & Steel, Hamilton, Ont.
Lon Cook, Insp. Foreman, Dominion Foundries & Steel, Hamilton, Ont.
***Moffats Ltd., Weston, Ont. (W. T. Snowdon, Fdry. Supt.).**
Joseph W. Robinson, J. Robinson & Son., Ottawa, Ont.
R. Robinson, Plant Supt., Moffats Ltd., Weston, Ont.
Fred J. Rutherford, Sales Repr., National Refractories Ltd., Hamilton, Ont.
James Stuart, Supv. Casting Insp., Dominion Foundries & Steel, Hamilton, Ont.

PHILADELPHIA CHAPTER

Roy Dreibelbis, Asst. Met., Stanley G. Flagg & Co. Inc., Stowe, Pa.
Herbert R. Greene, Engr., Simonds Abrasive Co., Philadelphia.
Frank J. Haines, Met., Stanley G. Flagg & Co., Inc., Stowe, Pa.
Charles H. Kneisley, Lancaster Malleable Castings Co., Lancaster Pa.
Anthony F. Raczynski, Asst. Works Engr., Stanley G. Flagg & Co. Inc., Stowe, Pa.
Harry J. Richmond, Lancaster Malleable Castings Co., Lancaster, Pa.

George H. Rote, Lancaster Malleable Castings Co., Lancaster, Pa.
Richard E. Vaughn, Branch Mgr., Peninsular Grinding Wheel Co., Detroit.

QUAD CITY CHAPTER

Leslie W. Ellis, Melting Dept., Union Malleable Iron Co., East Moline, Ill.
Dan Murphy, Fdry Fore., Union Malleable Iron Co., East Moline, Ill.

ROCHESTER CHAPTER

George C. Hubbard, Supt., Delco Appliance Div., GMC., Rochester, N. Y.

SAGINAW VALLEY CHAPTER

Foster C. Bennett, Met., Dow Chemical Co., Midland, Mich.
M. C. Godwin, Asst. Supt., Bostick Foundry Co., Lapeer, Mich.
Charles Schneider, Supt., Brisk Foundry & Machine Co., Imlay City, Mich.

SOUTHERN CALIFORNIA CHAPTER

Earl K. Appleman, Refractory Engr., A. P. Green Fire Brick Co., Los Angeles.
Engineering Library, University of California, Los Angeles.

TEXAS CHAPTER

Ralph Hassett, Patt. Shop Foreman, Texas Foundries, Inc., Lufkin, Texas.
H. S. Hipple, Abrasive Engr., Simonds Abrasive Co., Philadelphia.
Robert C. Wittlinger, Allis-Chalmers Mfg. Co., Milwaukee.

TWIN CITY CHAPTER

James H. Anderson, Instructor Fdry. Dept., University of Minnesota, Minneapolis.
Earl F. Kimes, The Dotson Company, Mankato, Minn.

WESTERN MICHIGAN CHAPTER

Harvey R. Anderson, Supt., Standard Pattern & Model Works, Muskegon Heights, Mich.
Robert B. Anderson, Standard Pattern & Model Works, Muskegon Heights.

WESTERN NEW YORK CHAPTER

Richard H. Beyer, Sec'y., Inter-Allied Foundries of New York State, Buffalo, N. Y.

WISCONSIN CHAPTER

John L. McIlhone, Met., International Harvester Co., Waukesha, Wis.
Lloyd Quirk, Carpenter Brothers, Inc., Milwaukee.
Dave A. Salentine, Salentine Equipment Co., Milwaukee.
Ray Schabowsky, Div. Supt., Tri-Clover Machine Co., Kenosha, Wis.
Norman James Stickeny, Met. Student, University of Wisconsin, Madison, Wis.

OUTSIDE OF CHAPTER

Raymond Lyons, Washington Stove Works, Everett, Wash.
Muhammad Anwar-ul Haque, State College, Pa.
*Sonken Galamba Corp., Kansas City, Kan. (Henry C. Deterding, Met.).

Belgium

N. V. Standaard Boekhandel, Huidevettersstraat 57-59, Antwerp.
Paul Ropsy, Administrateur Delegue, Societe Belge Griffin, Merxen, Antwerp.

Brazil

Dr. Any F. Torres, Director Supv., Cia. Brasileira de Material Ferroviario, Sao Paulo.

China

Hua Shih-jung, 1193 Rue Lafayette, Shanghai.

India

Robert Templeton Bell, Journeyman, B. B. & C. I. Railway, Ajmer, Rajputana.

South Africa

Alexander Koppel, Engr., Koppel Engineering Pty. Ltd., Johannesburg.
J. J. Marais, G. & W. Industrial & Chemical Supplies (Pty.) Ltd., Johannesburg.

Sweden

A. B. Kanthal, Halstahammar.
Sten Rudberg, Captian, Aktiebolaget Jarnforadling, Halleforsnas.
Bengt Magnusson, Mech. Engr., Husgvarna Vapenfaboiks A. B. Huskvarna.
Folke Nilsson, Chief Met. Engr., Uddeholms A/B, Hagfors.

Switzerland

Robert Bertschinger, Dr. Ing. habil. Brohburgstrasse 79, Zuerich.

SHAPE PROGRAM
For Chicago Conference

EXPANDING PLANS for the Chicago Regional Foundry Conference, Nov. 21-22, neared completion as the arrangements committee, meeting recently at the National Office under chairmanship of A. W. Gregg, Whiting Corp., Harvey, Ill., established the site, the Continental Hotel, Chicago, and decided upon a number of outstanding speakers.

Men attending the initial technical session, Thursday morning, Nov. 21, will hear a discussion of "Good Housekeeping and Plant Maintenance," by James Thomson, chief works engineer, Continental Foundry & Machine Co., East Chicago, Ind., who serves as Chairman, A.F.A. Plant and Plant Equipment Committee.

Malleable section expects to feature at its first session a paper by Dr. C. H. Lorig, Battelle Memorial Institute, Columbus, Ohio, Chairman, A.F.A. Steel Division, with W. D. McMillian, International Harvester Co., Chicago, serving as chairman.

Papers by J. H. Lansing, consulting engineer, Malleable Founders' Society, Cleveland, member of the Executive Committee, A.F.A. Malleable Division, and W. R. Jaeschke, Whiting Corp., are scheduled for the second and third malleable sessions, respectively; and B. C. Yearley, National Malleable & Steel Castings Co., Cicero, Ill., and C. C. Lawson, Wagner Malleable Iron Co., Decatur, Ill., will act as chairmen.

Plans for the pattern section call for discussion of patterns for the jobbing foundry, metal patterns for production foundries, pressure plates, and core boxes and core driers. H. K. Swanson, Swanson Pattern and Model Works, East Chicago, Ind., is chairman of the patternmaking committee.

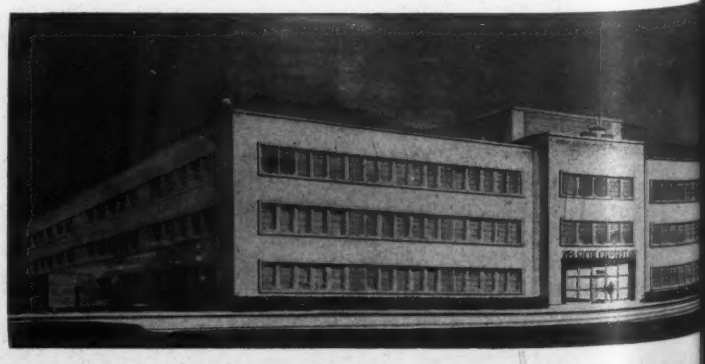
Clifton Utley, famed news commentator, will be the speaker at the conference banquet Thursday night; while D. —. Heald, Illinois Institute of Technology, Chicago, will address the first luncheon, Thursday; and Dean O. W. Esbach, Northwestern Technological Institute, Northwestern University, Evanston, Ill., the Friday luncheon.

Address of welcome, Thursday morning, will be delivered by Dr. H. F. Moore, University of Illinois, Urbana.

The Chicago regional conference of 1946 is sponsored jointly by the Chicago and Central Illinois A.F.A. chapters, Illinois Institute of Technology, Northwestern University, and University of Illinois; and is the fourth in a series started in 1938.

The last Chicago regional conference was held in October, 1941, at Purdue University, West Lafayette, Ind.

Architect's drawing of Velsicol Corporation's new office and laboratory now being constructed in Chicago.



★ CHAPTER ACTIVITIES ★

news

Central Ohio

Karol Whitlatch
Aetna Fire Brick Co.
Chapter Secretary

ROUND TABLE DISCUSSIONS of melting practices for iron and steel, the former led by H. R. Warsmith, Jeffrey Mfg. Co., Columbus, Ohio, and the latter by F. O. Lemmon, Ohio Steel Foundry Co., Springfield, Ohio, comprised the technical program of Central Ohio A.F.A. chapter's May 27 meeting at the Chittenden Hotel, Columbus. Approximately 80 members and guests were in attendance for this final meeting of the season, also marked by the election of chapter officers and directors.

Named *Chairman* for 1946-47 was J. J. Dunbeck, Eastern Clay Products, Inc., Eifort, Ohio, chapter Co-Chairman for the current year, and well known to many A.F.A. members as a frequent speaker at chapter meetings. R. H. Frank, Bonney-Floyd Co., Columbus, currently serving as chapter Treasurer, was elected *Co-Chairman.*

J. S. Schram, Swan-Finch Oil Corp., Columbus, was chosen as chapter *Secretary.*

W. L. Deutsch, Columbus Malleable Iron Co., of that city, was elected *Treasurer.*

Named to serve one-year terms as chapter *Directors* were: Tom Barlow, Battelle Memorial Institute, Columbus, retiring chapter Chairman; H. R. Warsmith; F. O. Lemmon, and Karol Whitlatch, Aetna Fire Brick Co., Oak Hill, Ohio.

New England

M. A. Hosmer
Hunt-Spiller Mfg. Corp.
Association Reporter

NEW DEVELOPMENT in foundry technology supplied the topic of the evening for the regular meeting of New England Foundrymen's Association, June 12, at the Engineers' Club, Boston, with 120 members and guests present to hear R. T. Wise, consulting engineer, New York, discuss "Dielectric Baking of Sand Cores."

President W. B. Hagerman, Rice-Barton Corp., Worcester, Mass., introduced the speaker of the evening. Mr. Wise described the method of baking sand cores prepared with a special water-soluble binder, which process has been developed within the past two years.

Equipment consists of a dielectric generator and a conveyor belt running through a drying tunnel, and is described as compact, easily operated and reasonable in price. Setup can be located on the molding floor, in order to obviate transportation.

The speaker cited advantages of the method, including: short time required for baking, giving as an example an instance in which a core, requiring one hour by conventional methods, was baked in 30 seconds; reduction in core oven equipment normally required; and good collapsibility and high tensile strength in cores produced. Mr. Wise stated that, although the core is thoroughly baked, it alone is heated, little or no heat being transferred to the surrounding room or the floor and core boxes, plates, etc. The latter, however, must be made of non-metallic material, such as plastic.

Mr. Wise presented lantern slides to illustrate his points; and following his remarks, the meeting was thrown open to general discussion.

Metropolitan

C. J. Law
Worthington Pump & Machinery Corp.
Chapter Director

ANNUAL MEETING of Metropolitan A.F.A. chapter was held at the Essex House, Newark, N. J., June 3, with 150 members and guests attending for election of officers and directors and a featured discussion of "Synthetic Foundry Sands," by N. J. Dunbeck, Eastern Clay Products, Inc., Eifort, Ohio.

Among the guests was Philadelphia Chapter Chairman J. M. Robb, Jr.,

Views of the Annual Meeting of Eastern Canada and Newfoundland chapter, May 15, at Mount Royal Hotel, Montreal. From speaker's table (top), Chapter Vice-President Henri Louette, Warden King, Ltd., Montreal, addresses the gathering.

(Photo courtesy John Bing, A. P. Green Fire Brick Co.)

New officers of Northern Illinois-Southern Wisconsin chapter: left to right, President John Doerfner, Jr., Gunite Foundries Corp., Rockford, Ill.; Vice-President J. T. Clausen, Greenlee Bros. & Co., Rockford; and Treasurer Lester Fill, Geo. D. Roper Corp., Rockford.

Hickman Williams & Co., Philadelphia.

H. A. Deane, American Brake Shoe Co., New York, retiring Chairman of Metropolitan chapter, reported a membership of 375, and noted the fine attendance at meetings of the past season. Also cited was a gratifying interest in chapter-sponsored educational meetings.

Members next proceeded with elections, and H. L. Ullrich, Sacks-Barlow Foundries, Inc., Newark, N. J., who served as Chapter Vice-Chairman for the 1945-46 season, was chosen *Chairman* for the coming year. K. A. DeLonge, International Nickel Co., New York, was elected *Vice-Chairman.*

Elected *Secretary* was J. F. Bauer, Hickman Williams & Co., New York.

D. Polderman, Jr., Whiting Corp., New York, was chosen to continue as *Treasurer,* in which capacity he has served since the recent transfer of H. B. Caldwell, of the same firm.

Chapter *Directors* elected to serve a two-year term, are: D. Frank O'Connor, American Saw Mill Machine Co., Hackettstown, N. J.; A. L. Fischer, Fischer Castings Co., Plainfield, N. J.; B. E. Beldin, Whitehead Bros. Co., New York; B. N. Ames, U. S. Navy Yard, Brooklyn, N. Y.; and Philip Van Duyne, Meeker Foundry Co., Newark. T. J. Wood, American Brake Shoe Co., Mahwah, N. J., was elected *Director* for one year, to complete the unexpired term of Alexander McIntosh.

In the technical session which followed, Mr. Dunbeck, an active member of various committees in A.F.A. Foundry Sand Research Project, stressed the abundance of published data on fire clay and bentonite, available to the foundryman. "There is little of the mysterious left," stated the speaker. "The foundryman is in position to make a wise and intelligent choice of bond."

Foundries having a sand reclaiming system can readily change to synthetic sands, Mr. Dunbeck suggested; while those which have no reclaiming system have a harder problem, as an intimate mixture of the sand, selected bond and moisture is required. Properties of synthetic sands were enumerated; and it was indicated that, through purchase and application of materials available, foundrymen can obtain properties to suit his requirements.

Henry Mackler, Singer Mfg. Co., Elizabeth, N. J., acted as technical chairman for the general discussion.

Philadelphia

E. C. Troy
Dodge Steel Co.
Chapter Director

FINAL MEETING of the current season for Philadelphia A.F.A. chapter, held May 24 at the Engineers Club, Philadelphia, drew a good attendance, despite the railroad strike, for a program featured by three capable foundrymen: A.F.A. Gold Medalist John Howe Hall, steel foundry consultant, Swarthmore, Pa., as technical chairman; and John Erler and G. T. Hassard, both of Farrel Birmingham Co. Inc., Ansonia, Conn., as speakers.

Mr. Erler, member Executive Committee, A.F.A. Gray Iron Division, discussed the need for greater cooperation between designer, foundryman and inspector — exhibiting, through slides, instances of unnecessary casting failures. The speaker pointed out that, through ignorance of application and of critically-stressed areas, foundrymen frequently produce a non-serviceable product; and suggested that they work together to establish principles that will aid designer and foundryman alike.

Following speaker, Mr. Hassard presented an interesting and comprehensive description of the manufacture of large gray iron castings, comparing costs and results between use of full patterns and core box assemblies. The speaker expressed definite preference for core box assemblies, citing improved quality and lower costs in his observations.

Numerous sidelights to the subjects discussed were added by the technical chairman, Mr. Howe, who serves as a member of the Executive Committee, A.F.A. Steel Division, as well as on several other A.F.A. national groups. Mr. Howe also brought several interesting questions from the floor during the general discussion period.

Earlier, during the business session, results of chapter elections were announced.

Chosen to head the chapter as *Chairman* for the 1946-47 season was B. A. Miller, Cramp Brass & Iron Foundries Div., Baldwin Locomotive Works, Philadelphia, who served as Vice-Chairman during the past year.

E. C. Troy, Dodge Steel Co., Philadelphia, currently a Chapter Director, was named *Vice-Chairman.*

W. B. Coleman, W. B. Coleman & Co., Philadelphia, continues as *Secretary-Treasurer.*

Elected to serve three-year terms as chapter *Directors* were: William Morley, Link Belt Co., Olney Fdry. Div., Philadelphia, and A. C. Gocher, Fletcher Works, of the same city.

Northeastern Ohio

W. G. Gude
The Foundry
Chapter Reporter

IN ATTENDANCE FOR Old Timers Night at Northeastern Ohio A.F.A. chapter, May 23, at the Cleveland Club, were 130 veterans of 40 or more years in the industry and a

number of prize-winning apprentices, among the 335 members and guests.

Presiding officer at the meeting, last of the current season, was Chapter President A. C. Denison, Fulton Foundry & Machine Co., Cleveland, who introduced the winners of the local apprentice contests and, together with H. E. Ennis, secretary, Associated Industries of Cleveland, presented the awards.

Successful contestants were: John Pietrzyki, Crucible Steel Casting Co.; Steve Grabowski, Meech Avenue Foundry; Harold Young, Cleveland Trade School; Robert Bina, Crucible Steel Casting Co., winner of first prize in the A.F.A. National Apprentice Contest; Sam Colombo, of the same firm; and Jim Kraynak and Frank Alabise, West Steel Casting Co., all of Cleveland.

Election of chapter officers and directors concluded the business of the evening.

H. J. Trenkamp, Ohio Foundry Co., Cleveland, chapter Vice-President for 1945-46, was elected *President;* and Bruce Aiken, Crucible Steel Casting Co., of the same city, currently a chapter Director, was named *Vice-President.*

Named to continue as *Secretary* was G. J. Nock, Nock Fire Brick Co., Cleveland.

F. R. Fleig, Smith Facing and Supply Co., Cleveland, was re-elected *Treasurer.*

Elected to three-year terms as *Directors* were: Vincent Sedlon, Master Pattern Co.; W. E. Sicha, Aluminum Co. of America; F. J. Pfarr, Lake City Malleable Co.; W. G. Gude, *The Foundry,* all of Cleveland; and C. S. Winter, Duplex Mfg. & Foundry Co., Elyria, Ohio.

Entertainment, which featured the balance of the evening, was arranged by the committee under chairmanship of L. P. Robinson, Werner G. Smith Co., Cleveland.

Chesapeake

W. H. Baer
Naval Research Laboratory
Chapter Reporter

ILLUSTRATED DISCUSSION of mining and processing various grades of foundry sands was presented to the May 24 meeting of Chesapeake A.F.A. chapter, at the Engineers' Club, Baltimore, Md., with Chapter Vice-President David Tamor, American Chain & Cable Co., York, Pa., presiding and H. J. Williams, New Jersey Silica Sand Co., Millville, N. J., as speaker of the evening.

Mr. Williams, a member of the Committee on Grading and Fineness, A.F.A. Foundry Sand Research Project, accompanied his remarks with a series of Kodachrome slides, as he discussed such phases as initial mining operations, washing, grading and storage of sands. In several instances, the speaker explained the part laboratory control plays in establishment of uniform quality.

Following Mr. Williams' remarks, Mr. Tamor called on Chapter Director H. A. Horner, Frick Co. Inc., Waynesboro, Pa., to open the general discussion period; and J. E. Crown, U. S. Navy Yard, Washington, D. C., together with other members, also contributed comments of interest.

Canton District

N. E. Moore
Wadsworth Testing Laboratory
Chapter Reporter

SECOND SEASON of the Canton District A.F.A. chapter closed with its meeting of May 23, at Mergus Restaurant, Canton, Ohio, and 84 members and guests were on hand for the introduction of new officers and directors and a technical discussion of "Core Blowing," by Zigmond Madacey, Caterpillar Tractor Co., Peoria, Ill.

Mr. Madacey, recently elected Chairman of Central Illinois chapter, presented a comprehensive discussion of forming of cores by blowing. Among advantages cited were: speed of production, uniformity of quality and accurate dimensions. Sand control, which plays an important part in elimination of core troubles, was discussed at length.

W. W. Maloney, Secretary, American Foundrymen's Association, who was among the guests, spoke briefly regarding the role of the Association in industry, its policies and objectives, and its plans for the immediate future.

Officers for the coming season and new directors were presented by the retiring chapter Chairman, H. G. Robertson, American Steel Foundries, Alliance, Ohio.

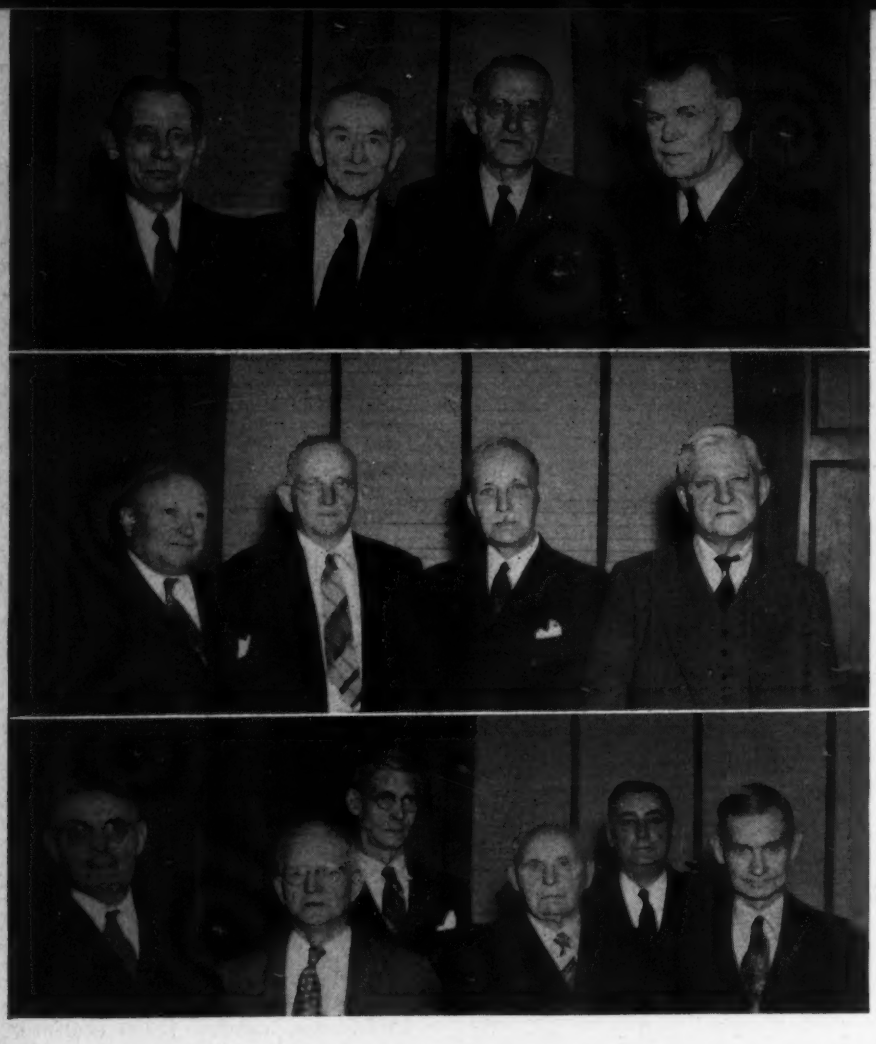
Current Chapter Vice-Chairman I. M. Emery, Massillon Steel Casting Co., Massillon, Ohio, will serve as *Chairman* for 1946-47; and C. F. Bunting, Pitcairn Co., Barberton, Ohio, was named *Vice-Chairman.* Mr. Bunting was one of the two Vice-Chairmen of the 1945-46 season.

Chosen as *Secretary* was C. B. Williams, Massillon Steel Casting Co., who has served as Chapter Director.

O. D. Clay, Tuscora Sand Co.,

Members and guests of Northwestern Pennsylvania chapter, who gathered at the Moose Club, Erie, May 27, for election of chapter officers, demonstrated appreciation and enthusiasm for both the program and the fare.

(Photos courtesy C. H. Gleba, General Electric Co.)



(Photos courtesy John Bing, A. P. Green Fire Brick Co.)

Some of the Old Timers honored at the May 14 meeting of Northern Illinois-Southern Wisconsin chapter at the Faust Hotel, Rockford, Ill.

Canal Fulton, Ohio, continues as *Treasurer.*

Directors for the three chapter areas are: Central, K. F. Schmidt, United Engineering & Foundry Co.; T. M. Dubs, Canton Pattern & Mfg. Co., and M. J. Winters, Winters Foundry & Machine Co., all of Canton.

Eastern, H. G. Robertson, C. J. Trump, Machined Steel Castings Co., Alliance, and F. C. Glass, Deming Co., Salem, Ohio.

Western, Robert Cairnie, Orrville Bronze & Aluminum Co., Orrville, Ohio; C. W. McLaughlin, Lectromelt Steel Castings Co., Barberton, and E. H. Taylor, F. E. Myers & Bros. Co., Ashland, Ohio.

Northwestern Pennsylvania

E. M. Strick
Erie Malleable Iron Co.
Chapter Vice-Chairman

ANNUAL ELECTION of officers and directors was held by Northwestern Pennsylvania A.F.A. chapter at its May 27 meeting, in the Moose Club, Erie, Pa.; and National Director-Elect B. L. Simpson, National Engineering Co., Chicago, presented the technical discussion of the evening on "The History and Development of the Foundry Industry."

Mr. Simpson drew upon material from his forthcoming book to portray the growth of the castings industry from its crude beginnings to its present status, and asserted that the time is drawing near when every foundry will be so equipped as to make it the best of places in which to work.

Retiring Chapter Chairman R. W. Griswold, Jr., Griswold Mfg. Co., Erie, received tribute for his part in making the season one of memorable accomplishments, and was accorded a standing round of applause as he turned the gavel over to his successor, E. M. Strick, Erie Malleable Iron Co., Erie, current Vice-Chairman and elected *Chairman* for 1946-47.

John Clarke, General Electric Co., Erie, was elected *Vice-Chairman.* Other officers are:

Secretary, H. L. Gebhardt, United Oil Mfg. Co., Erie, who served in the same capacity for the 1945-46 season.

Treasurer, Douglas James, Cooper-Bessemer Corp., Grove City, Pa.

Directors, term ends 1949: George Johnstone, Grove City, Pa.; J. A. Shuffstall, National Erie Corp., and John Gill, Lakeshore Pattern Works, both of Erie.

Term ends 1948: Clarence Fitts, Hays Mfg. Co., Erie; T. M. Beaulac, Chicago Pneumatic Tool Co., Franklin, Pa.; and F. J. Eisert, Urick Foundry Co., Erie.

Term ends 1947: R. D. Carver, Standard Stoker Co., Erie; J. S. Hornstein, Meadville Malleable Iron Co., Meadville, Pa.; W. J. Miller, F. B. Stevens, Inc., Erie; and R. W. Griswold, Jr.

Southern California

J. B. Morey
International Nickel Co.
Chairman, Publicity Committee

INTERPRETATION OF BLUEPRINTS was the evening's topic for the May 24 meeting of Southern California A.F.A. chapter, in Roger Young Auditorium, Los Angeles; and a good crowd of foundrymen turned out despite a local transportation strike, to hear Assoc. Prof. E. R. Mertz, University of Southern California, Los Angeles, discuss "Blueprint Reading," and R. A. Lewis, Los Angeles Steel Castings Co., of that city, detail short cuts to determination of casting weights.

Professor Mertz illustrated his

Speakers of the evening at Southern California chapter's May 24 meeting, Assoc. Prof. E. R. Mertz (left), University of Southern California, Los Angeles, and R. A. Lewis (right), sales manages, Los Angeles Steel Castings Co., of that city, talk over the program with Chapter President R. R. Haley, Advance Aluminum & Brass Co., Los Angeles.

Views of the May 24 meeting of Philadelphia chapter, well attended despite railroad strike. Center (left to right): G. T. Hassard, Farrel-Birmingham Co. Inc., Ansonia, Conn., who discussed unnecessary casting failures; technical chairman J. H. Hall, foundry consultant, Swarthmore, Pa.; and John Erler, Farrel-Birmingham Co., who spoke on manufacture of gray iron castings and the need for greater cooperation between foundrymen, designer and inspector.

fast-moving and instructive remarks with a number of practical slides, and stressed the relative ease with which drawings can be interpreted once basic principles are understood. The speaker brought out the point that foundries are not usually furnished with a finished machine drawing, and must, therefore, mark up dimensions to include required finish.

Mr. Lewis then took up the subject of weight determination, describing various methods and indicating that even the most complicated designs may be undertaken with confidence after a foundryman has acquired a little experience. Several existing types of slide rules and estimating cards were discussed.

Business session of the evening featured election of chapter officers and directors. Chosen as chapter *President* for the coming season was W. D. Emmett, Los Angeles Steel Castings Co., of that city, who served in the capacity of Vice-Chairman for 1945-46. H. E. Russill, Eld Metal Co. Ltd., Los Angeles, Secretary during 1945-46, was named *Vice-President.*

L. O. Hofstetter, Brumley-Donaldson & Co., Los Angeles, who completes a term as Treasurer with this season, was named *Secretary.*

Elected *Treasurer* was E. D. Shomaker, Kay-Brunner Steel Products Co., Alhambra, who has been the competent chairman of the chapter entertainment committee.

Directors, elected for a two-year term, are: J. E. Wilson, Climax Molybdenum Corp.; Lester Rankin, Alameda Mfg. Co.; Roy Nash, Magnesium Products, Inc.; and J. B. Morey, International Nickel Co., all of Los Angeles.

Following the meeting of May 24, Southern California chapter held its first annual "Ladies' Night," May 25, at Lakewood Country Club.

Chicago

E. F. Ross
The Foundry
Chapter Reporter

PANEL DISCUSSION SUPPLIED an interesting and valuable technical program for 100 members and guests of the Chicago A.F.A. chapter meeting, May 24, at the Chicago Bar Association. A group of capable foundrymen, pinch-hitting on the topic, "Castings In the Postwar Industry," rounded out a meeting that was successful despite the national railroad strike, which prevented the speaker of the evening from fulfilling his engagement and halted commuter service in the city area 90 minutes before meeting time.

Chapter President J. C. Gore, Werner G. Smith Co., Chicago, presided at the dinner and the annual business meeting, at which chapter officers and directors were elected; and Chapter Vice-President L. H. Hahn, Sivyer Steel Casting Co., Chicago, was in the chair for the technical program.

Keynote address on the panel topic was given by A. W. Gregg, Whiting Corp., Harvey, Ill. Mr. Gregg, who serves as Chairman, A.F.A. Committee on Training Graduate Engineers in Industry, emphasized recent developments that will benefit casting production and make the foundry a better place in which to work.

Outlook for gray iron was portrayed by E. W. Smith, Jr., Lindahl Foundry Div., American Gear & Mfg. Co., Chicago, who cited advance of gray iron during the war, improved facilities now available, possibilities for economies in production and other similar aspects.

Higher standards for castings and the part they will play in postwar industry were reviewed by S. C. Massari, A.F.A. National Office. The non-ferrous field was discussed by Oscar Blohm, Hills-McCanna Co., Chicago, member Executive Committee, A.F.A. Aluminum and Magnesium Division, who referred chiefly to the two light metals.

What the foundryman wants in the way of patterns was considered by H. J. Jacobson, Industrial Pattern Works, Chicago, who described a questionnaire, designed to obtain all pertinent information, which his shop submits to customers. Also contributing to the discussion were Martin Rintz, Continental Foundry & Machine Co., East Chicago, Ind., and F. B. Skeates, Link-Belt Co., Chicago, Ill.

Chapter election resulted in acceptance by unanimous vote of the

H. J. Williams (left), New Jersey Silica Sand Co., addressing the May 24 meeting of Chesapeake chapter.

(Photos courtesy E. T. Myskowski, Naval Research Laboratory)

Saginaw Valley chapter chose its new officers and directors at the annual business meeting, May 2, in Frankenmuth, Mich.; and the photographer caught these scenes. Top, an informal chat among: Chapter Chairman J. F. Smith, Chevrolet Grey Iron Foundry, General Motors Corp., Saginaw; speaker of the evening Morris Bean, Morris Bean Co., Yellow Springs, Ohio; W. G. Mixer, Buick Motor Div., General Motors Corp., Flint; and Chapter Secretary-Treasurer-Elect F. S. Brewster, Dow Chemical Co., Bay City, Mich.

recommendations of the nominating committee.

Chapter Vice-President L. H. Hahn was advanced to *President;* and F. B. Skeates was named *Vice-President.*

L. C. Smith, recently associated with Peninsular Grinding Wheel Co., Chicago, was elected *Secretary* (since resigned due to accepting position out of town), in which capacity he served for the 1945-46 season.

Directors elected to serve a three-year term are: C. V. Nass, Pettibone-Mulliken Corp., Chicago; D. H. Lucas, manufacturer's representative, Chicago; H. K. Swanson, Swanson Pattern & Model Works, East Chicago, Ind.; and J. C. Gore, retiring chapter president.

Central Illinois

C. W. Wade
Caterpillar Tractor Co.
Chapter Secretary

ENTHUSIASM FOR accomplishments of its abbreviated first season (starting December, 1945) and prospects for the future was evident as Central Illinois A.F.A. chapter held its last meeting before adjournment for summer months, at Jefferson Hotel, Peoria, Ill., on May 20. In attendance for the first formal election of officers and directors were 127 members and guests, with Chapter Chairman L. E. Roby, Peoria Malleable Castings Co., Peoria, presiding.

National Director-Elect J. E. Kolb, Caterpillar Tractor Co., Peoria, first National Director elected from Central Illinois chapter, was introduced to those present. Speaker of the evening was W. A. Hambley, Allis-Chalmers Mfg. Co., Milwaukee, Chairman, Committee on Analysis of Casting Defects, A.F.A. Gray Iron Division, who presented a comprehensive analysis of "Casting Defects."

Following introduction of Mr. Kolb, Chapter Secretary C. W. Wade, Caterpillar Tractor Co., presented his report, commenting on the splendid progress of the chapter and outlining plans for the coming year. Chapter Treasurer A. V. Martens, Pekin Foundry & Mfg. Co., Pekin, Ill., presented his report on chapter finances.

Election of officers and directors was the next order of business; and the slate proposed by the chapter nominating committee was unanimously accepted.

Zigmond Madacey, Caterpillar Tractor Co., who has served as Vice-Chairman since November, 1945, was elected *Chairman;* and A. V. Martens, Treasurer for the interim period, was named *Vice-Chairman.*

Elected *Secretary-Treasurer* was C. W. Wade, who has served as Secretary of the group since its organization last fall.

Chapter *Directors* are: Term expires 1949, F. W. Shipley, Caterpillar Tractor Co., and L. E. Roby.

Term expires 1948, V. W. A'Hearn, Midwest Pattern Works, Peoria, and C. W. Buckler, Superior Foundry Co., East Peoria, Ill.

Term expires 1947, Adolph Klawitter, Peoria Foundry Div., M. H. Detrick Co., Peoria, and Prof. C. E. Schubert, University of Illinois, Urbana.

Following the election, Chairman Roby introduced Mr. Hambley, who prefaced his discussion by extending his congratulations to the chapter for its enthusiasm and outlining briefly the growth of A.F.A. in the last ten years. Foundrymen, advised the speaker, should stand behind the Association, the only society truly their own—principally setup, organized and used to promote education and desseminate information.

Mr. Hambley quickly demonstrated his command of his subject, listing

ten types of defects with which his remarks were concerned, and going into detail in regard to definition and cause. A series of slides, presented later, emphasized points raised in discussion. The speaker asserted that all foundries have defect problems, and that these can be eliminated by getting together and discussing them—bringing to bear truth and science which solve all problems.

In adjourning the meeting, Chairman Roby expressed his thanks to chapter members for the willing cooperation which resulted in a successful season.

Central New York

J. A. Feola
Crouse-Hinds Co.
Chapter Reporter

IMPROVEMENTS IN casting cleaning methods and equipment were detailed before Central New York A.F.A. chapter, meeting May 17 at Onondaga Hotel, Syracuse, with Chapter Chairman E. G. White, Crouse-Hinds Co., Syracuse, presiding. Bruce Artz, a member of the chapter, and A. L. Gardner, both of Pangborn Corp., Hagerstown, Md., were speakers for the technical session.

Mr. Artz discussed at length various types of casting cleaning equipment and merits of each method; and, next, introduced Mr. Gardner, who exhibited slides and a short movie in the course of tracing developments in such equipment from the first crude beginnings through airless barrels and rooms, water cleaning and special installations for particular jobs.

Both speakers pointed out that dust has now been virtually eliminated from cleaning departments, large work is being handled mechanically, and castings are being cleaned more thoroughly than in the past.

In the lively discussion period following their remarks, Mr. Artz and Mr. Gardner joined in answering the many questions raised by foundrymen present.

Central Indiana

B. P. Mulcahy
Citizens Gas & Coke Utility
Chapter Director

FUNDAMENTAL IMPORTANCE of the foundry industry and the dependence of a mechanized age on all forms of castings were clearly demonstrated at the May 20 meeting of Central Indiana A.F.A. chapter, in the Athenaeum, Indianapolis, as National Director-Elect B. L. Simpson, National Engineering Co., Chicago, discussed "The History and Development of the Foundry Industry." A. W. Anderson, International Harvester Co., Indianapolis, served as technical chairman.

Business portion of the meeting was concerned with election of chapter officers and directors. J. P. Lentz, International Harvester Co., currently serving as chapter Vice-Chairman, was elected *Chairman;* and William Ziegelmueller, Electric Steel Castings Co., Indianapolis, a chapter Director, was named *Vice-Chairman.*

Robert Langsenkamp, Langsenkamp-Wheeler Brass Works, Inc., Indianapolis, was re-elected *Secretary.*

Fred Kurtz, Electric Steel Castings Co., was named *Treasurer.*

Chapter *Directors,* chosen to serve a three-year term, are: R. S. Davis, National Malleable & Steel Castings Co., retiring chapter Chairman; Ray Fickenworth, C. & G. Foundry & Pattern Works; Allen Reed, General Refractories Co.; and William McClenon, American Foundry Co., all of Indianapolis.

Howard Kreps, Frank Foundries Corp., Muncie, Ind., was elected *Director,* to complete the unexpired term of William Ziegelmueller.

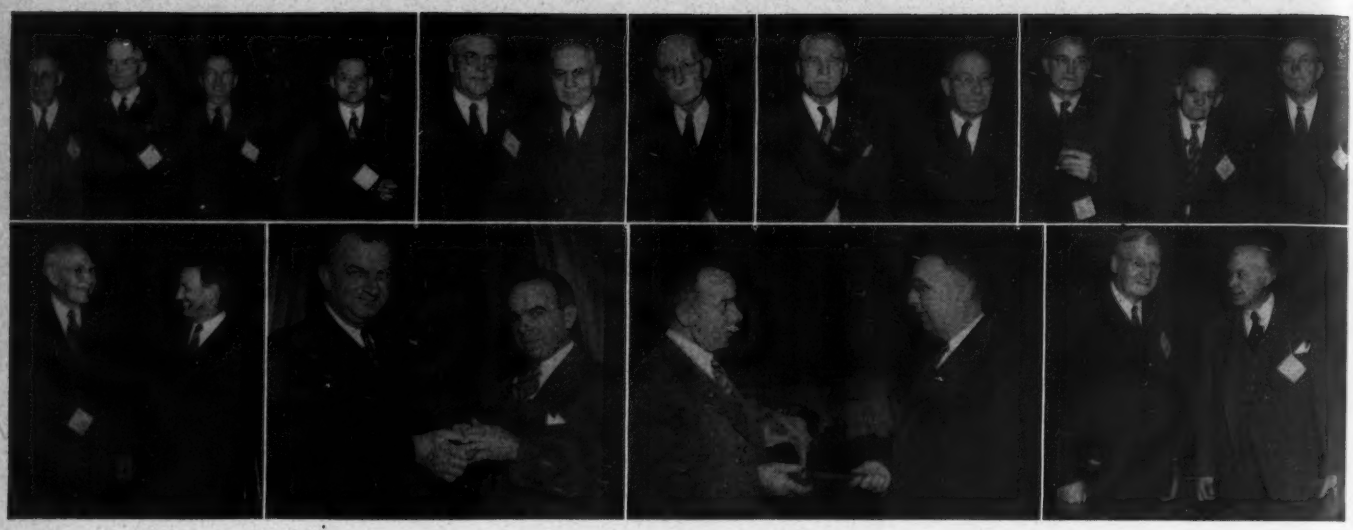
Birmingham District

J. P. McClendon
Stockham Pipe Fittings Co.
Chairman, Publicity Committee

PANEL DISCUSSION of "Operation and Maintenance of Mechanized Foundries" was the program of the evening May 17, at Tutwiler Hotel, Birmingham, as Birmingham District A.F.A. chapter closed a most successful season. More than 100 members and guests were present for the technical discussions and the election of chapter officers and directors.

J. A. Bowers, American Cast Iron Pipe Co., Birmingham, head of the chapter program committee, presided during the technical session.

Enjoying the evening's program of May 24, at Roger Young Auditorium, Los Angeles, new Southern California chapter officers (top) and retiring Chapter President R. R. Haley, Advance Aluminum & Brass Co., Los Angeles (second from left). New officers are, left to right: Treasurer E. D. Shomaker, Kay-Brunner Steel Products Co., Alhambra, Calif.; President W. D. Emmett, Los Angeles Steel Castings Co.; Vice-President H. E. Russill, Eld Metal Co. Ltd.; and Secretary L. O. Hofstetter, Brumley-Donaldson & Co., all of Los Angeles.



(Photos courtesy John Bing, A. P. Green Fire Brick Co.)

Scenes from the May 16 Old Timers Night of Wisconsin chapter, at Schroeder Hotel, Milwaukee. Bottom row, second from left, Chapter Director H. E. Ladwig, Allis-Chalmers Mfg. Co., Milwaukee, presents the president's ring to retiring Chapter President John Bing, A. P. Green Fire Brick Co., Milwaukee. Third photo from left shows Mr. Bing handing a new gavel to Chapter President-Elect David Zuege, Sivyer Steel Casting Co., of same city.

Speakers were: Morris Hawkins and L. L. Stone, Stockham Pipe Fittings Co., Birmingham; and W. J. Moore and J. L. Irwin, American Cast Iron Pipe Co.

During the business session, Chapter Chairman J. A. Woody, American Cast Iron Pipe Co., reviewed the activities and accomplishments of the chapter during the past year, and expressed appreciation for the work of committees and their chairmen.

Report of the chapter nominating committee was then presented by Chapter Secretary-Treasurer F. K. Brown, Adams, Rowe & Norman, Inc., Birmingham, and the membership proceeded with elections.

T. H. Benners, Jr., T. H. Benners & Co., Birmingham, Vice-Chairman for the current season, was elected *Chairman;* and W. E. Jones, Stockham Pipe Fittings Co., was elected *Vice-Chairman.*

F. K. Brown was named to continue as Birmingham's *Secretary-Treasurer.*

Directors elected were: Term expires 1949, J. A. Woody.

Term expires 1948, Thomas Bellsnyder, Jefferson Foundry Co.; D. B. Dimick, Jr., Dimick Casting Co.; and A. S. Holberg, Alabama Clay Products Co., all of Birmingham.

Term expires 1947, J. M. Bates, Moore-Handley Hardware Co., Birmingham.

National Director-Elect B. L. Simpson (second from right, top), National Engineering Co., Chicago, shared the speaker's table with: left to right, Chapter Chairman-Elect J. P. Lentz, International Harvester Co., Indianapolis; Chapter Chairman R. S. Davis, National Malleable & Steel Castings Co., Indianapolis; A. W. Anderson, International Harvester Co., technical chairman; and Chapter Vice-Chairman-Elect William Ziegelmueller, Electric Steel Castings Co., Indianapolis, at the May 20 meeting of Central Indiana chapter. Mr. Simpson was speaker of the evening on "History and Development of the Foundry Industry."

Detroit

ANNUAL MEETING of Detroit A.F.A. chapter, at Rackham Educational Memorial, Detroit, May 16, was concerned with election of officers and directors.

A. H. Allen, Penton Publishing Co., Detroit, who served as Vice-Chairman for the past season, was elected *Chairman;* and C. E. Silver, Michigan Steel Castings Co., Detroit, who has served as Chapter Director, was named *Vice-Chairman.*

R. E. Cleland, Eastern Clay Products Inc., Detroit, was chosen to continue as *Secretary.*

W. W. Bowring, Frederic B. Stevens, Inc., Detroit, was re-elected *Treasurer.*

New chapter *Directors,* elected to serve a three year term, are: Pierce Boutin, Pontiac Motor Div., General Motor Corp., Pontiac, Mich.; E. J. Burke, Hanna Furnace Corp., De-

troit; R. L. Orth, American Foundry Equipment Co., Detroit; and W. N. Seese, J. S. McCormick Co., Grosse Pointe Farms, Mich.

E. C. Hoenicke, Foundry Div., Eaton Mfg. Co., Detroit, retiring Chapter President, was named *Director*, to serve a one-year term.

Rochester

D. E. Webster
American Laundry Machinery Co.
Chairman, Publicity Committee

TRIBUTE WAS PAID, at the annual business meeting of Rochester A.F.A. chapter, May 14, at the Hotel Seneca, Rochester, N. Y., to Chapter Director Henry B. Hanley, American Laundry Machinery Co., Rochester, who served as first Chapter President (1944-45), and was instrumental, earlier, in organization of the chapter.

The occasion, attended by 93 members and guests, was designated "Henry Hanley Night" and, following brief remarks by V. L. Whitehead, Jr., Buffalo, N. Y., a member of Western New York chapter, and Rochester Chapter Director H. G. Hetzler, Hetzler Foundries, Inc., Rochester, the guest of honor was presented with a gift by Chapter President W. F. Morton, The Anstice Co. Inc., of the same city.

In reply, Mr. Hanley, who is also a past A.F.A. National Director, stressed good fellowship developed by A.F.A. chapter activities, and discussed some of the highlights of his own foundry career.

As the next order of business, Chapter Secretary-Treasurer C. B. Johnson, Symington-Gould Corp., Rochester, reported on the chapter's financial standing and membership growth, commenting on the excellent attendance at meetings during the past year. Mr. Johnson introduced two new members: G. L. Cox, International Nickel Co., Rochester; and George Hubbard, Delco Appliance Div., General Motors Corp., Rochester.

Recommendations of the chapter nominating committee were presented by its chairman, Chapter Director H. G. Hetzler, and the proposed slate of officers and directors for 1946-47 was accepted by unanimous vote.

Elected *President* was W. G. Brayer, Bausch & Lomb Optical Co., Rochester, who served as chapter Vice-President during the 1945-46 season; while L. C. Gleason, Gleason Works, Rochester, currently serving as a Chapter Director, was named *Vice-President* of the Rochester chapter.

L. C. Kimpal, Rochester Gas & Electric Corp., of that city, assumes the position of *Secretary-Treasurer*.

Chapter *Directors* are: Term expires 1949; H. G. Hetzler, J. E. McHenry, Gleason Works, and C. B. Johnson.

Term expires 1948; D. E. Webster, American Laundry Machinery Co.; D. D. Baxter, Sterling Wheelbarrow Co., Rochester; and N. F. Clement, Rochester-Erie Foundry Corp., Rochester.

Term expires 1947; W. F. Morton, H. B. Hanley, and M. T. Ganzauge, General Railway Signal Co., Rochester.

Northern California

C. R. Marshall
Chamberlain Co.
Chairman, Publicity Committee

HARMONY IS THE KEYNOTE to advancement in the foundry, old timers and apprentices agreed, as they swelled attendance to a record 152 at Northern California A.F.A. chapter's May 16 meeting in their

Old Timers Night at Northeastern Ohio chapter, May 23, at the Cleveland Club. Bottom, among those honored was this group of men with 50 or more years service in the industry. Top left, a group of apprentice prize-winners who received awards and were introduced to the meeting by the presiding officer, Chapter President A. C. Denison, Fulton Foundry & Machine Co. Inc., Cleveland, shown at extreme right, top, seated at speaker's table with Chapter Vice-President-Elect Bruce Aiken, Crucible Steel Casting Co., Cleveland.

Sidelights on Northern California chapter's Old Timers and Apprentices Night, May 16. Left, Charles Hoehn, Sr., Enterprise Engine & Foundry Co., San Francisco; Chapter Vice-President Richard Vosbrink, Berkeley Pattern Works, Berkeley; and Chapter President Charles Hoehn, Jr., Enterprise Engine & Foundry Co., seem to be enjoying the entertainment, which included award-winning performance by soloist Manuel Codero (center), Phoenix Iron Works, Oakland, a 35-year old timer. Right, National Director S. D. Russell, Phoenix Iron Works, who reported on the Golden Jubilee Convention, shown with Mrs. Russell as they prepared to depart for 50th Annual A.F.A. Convention.

honor, held at Hotel Alameda, Alameda, Calif.; Chapter Director A. M. Ondreyco, Vulcan Foundry Co., Oakland, Calif., handling the program, and Chapter President Charles Hoehn, Jr., Enterprise Engine & Foundry Co., Oakland, presiding at the business session.

Among old timers present were: Charles Hoehn, Sr., Enterprise Engine & Foundry Co., 56 years in the industry; Alexander Guild, Vulcan Foundry Co., 52 years, and George Guild, of the same firm, 46 years; Charles Payne, San Francisco Iron Foundry, Inc., San Francisco, 46 years; August Souza, 35 years, and Les Moseno, 30 years, both of the Vulcan company; and John Gonzalves, H. C. Macaulay Foundry Co., Berkeley, Calif., 30 years.

Rounding out the total of honored guests were 25 apprentices, many of whom were attending their first meeting of the chapter; W. B. Lawrence, coordinator, Berkeley schools, and R. A. Paul, assistant editor, *Western Machinery and Steel World*, San Francisco.

Program chairman Andrew Ondreyco first called on National Director S. D. Russell, Phoenix Iron Works, Oakland, who presented an inspiring picture of foundry progress with a report on the Golden Jubilee Convention in Cleveland. Mr. Russell described the highly interesting exhibits and activities at the Convention itself, and installations and methods seen during plant visitations; and discussed briefly literature on new equipment and foundry supplies which he collected while at Cleveland.

Following speaker, Mr. Hoehn, Sr., sounded the keynote for the old timers, relating many interesting anecdotes of the "old days." Much of the progress in foundries of the area, Mr. Hoehn suggested, resulted from ideas and skills of workers of many nationalities, who were attracted to the locality.

Alexander Guild, who has been associated with Phoenix Iron Works since 1907, praised the activities of A.F.A., stating that it had "educated the employer," thus making the work of the employees easier.

Mr. Ondreyco, himself an old timer, added a few remarks before calling on Joe Melling, H. C. Macaulay Foundry Co., apprentice instructor, who discussed apprentice training. Mr. Melling stressed that "owners must take an interest in apprentices." "Boys should be given a wide variety of work, and not criticized if they make mistakes. Try to build confidence," he said.

William Hinde, Lynch Brass & Aluminum Foundry, Oakland, added his comments on the subject; and Joe Monte Verda, leadingman molder, Mare Island Navy Yard, gave a brief resume of apprentice training at Mare Island, Calif.

Cincinnati District

J. S. Schumacher
Hill & Griffith Co.
Chapter Vice-Chairman

CUPOLA CHARGING methods, by hand and mechanical means, were evaluated and compared for 85 members and guests of Cincinnati District A.F.A. chapter, at the May 13 meeting, in Engineering Society Headquarters, Cincinnati, by J. N. Richardson, Modern Equipment Co., Port Washington, Wis.; while wide variety in foundry setups were indicated through showing of three mo-

(Concluded on Page 109)

View of the record attendance at Northern California chapter's Old Timers and Apprentices Night, at Hotel Alameda, Alameda, Calif., May 16.

NEW LITERATURE

Problem of foundry patternmakers, faced with current heavy demand for lumber, is recognized in issuance by Western Pine Association, 510 Yeon Building, Portland 4, Ore., of two illustrated 20-page booklets: No. 40, "Sugar Pine for Perfect Patterns," and No. 41, "Idaho White Pine Ideal for Wood Patterns." Both are offered free of charge. Numerous suggestions on grade utilization are included; and it is noted that proper utilization of maximum number of grades will decrease difficulties in obtaining material. Description of each grade suitable for patterns is incorporated; along with a list of standard manufactured sizes of rough and dressed selects, factory and board grades, and helpful suggestions on seasoning and storage.

"Photoelastic Stress Analysis," is surveyed in an 8-page folder, offered free of charge by Eastman Kodak Co., Rochester 4, N. Y. Background information and basic working specifications for this technique are given.

Production standards, methods, laboratory control facilities and history of Caterpillar Tractor Co., Peoria, Ill., are portrayed in a 32 page booklet, "Men of Vision," presented by the company. Development of tractor equipment from the days of the firm's early predecessors to the present is described and interpreted in terms of mechanical pioneering and economic and social significance. Numerous illustrations picture the company's products and facilities and their applications.

Consideration is given one of industry's important machine tool problems in "Depreciation vs. Obsolence," an illustrated booklet published by Kearney & Trecker Corp., Milwaukee 14. Statistics are presented on an economic aspect of operations vital to every business.

Installation pictures and easy to use tables and charts on temperature conversion and thermal efficiency of fuels are contained in a 16-page booklet, "Engineered Heat," designed for engineers and production men. Included is descriptive information on soaking pits, various types of heating furnaces and auxiliary equipment manufactured by Salem Engineering Co., Salem, Ohio, from whom copies are obtainable on request.

Specifications and applications of Jessop steels are presented in a 16-page catalog issued by Jessop Steel Co., Washington, Pa.

"Products of Eaton," describing items made by Eaton Manufacturing Co., Cleveland 10, for automotive, marine and airplane fields, is a well illustrated 44-page booklet now ready for distribution. Several new products scheduled for production, as well as the established line, are described and shown.

Detailed information on the new 60x96-in. "Wheelabrator Tumblast" —largest ever built, including installation photographs, construction features, overall dimension drawings and specifications, are contained in 16-page Catalog No. 264, obtainable from American Foundry Equipment Co., 555 South Byrkit St., Mishawaka, Ind.

"Shot Peening . . . What it Means to You," is title of a 16-page brochure, illustrated with drawings charts and photographs, covering application of shot peening and incorporating performance data. Result of two years preparation, the booklet will be sent at no charge on request to Pangborn Corp., Hagerstown, Md.

Visit to a modern steel foundry can be accomplished in the pages of a handsomely illustrated brochure, "100 Acres of Skill and Steel—a Visit to Scullin Steel Co., St. Louis," just published by the company. Furnace and laboratory operations are illustrated, and successive steps in production of castings are pictured. Information on the company's war and peacetime products is given. Copies free on request from Scullin Steel Co., 6700 Manchester, St. Louis, Mo.

New additions to foundry literature available at no charge to members of the industry, from Whiting Corp., Harvey, Ill., are: "Useful Information for Foundrymen," Bulletin FY-40, a forty-page revision of the popular publication formerly known as "Useful Information," containing tables, data and general information and bound in handy pocket size; "How to get Uniformity in Hot Metal," Bulletin FY-139, containing illustrations and charts showing features of Cradle Furnaces; "Presenting the Pour-Rite Ladle," Bulletin FY-141, describing this new unit featuring air-cooled trunnions; and "Crane Maintenance Cost Record," a handy, simple form on which figures from maintenance work orders and time and material tickets are entered to show which cranes pay their way.

Complete information on the line of conveyor, transmission and elevator belts manufactured by Hewitt Rubber Div., Hewitt-Robins, Inc., Buffalo, N. Y., is included in a loose-leaf two-color catalog, written in simple non-technical terms. Maintenance suggestions on prolonging belt life are given; sectional drawings demonstrate belt construction, and applications are shown in plant photographs. Copies may be secured on request.

Foundrymen and designers will find information on properties and advantages of "Ternalloy" aluminum alloys in a new illustrated bulletin available from National Smelting Co., 6700 Grant Ave., Cleveland 5. Details of aging characteristics and physical properties as sand or chill cast, are included.

Basic information on materials and methods used in making refractory concrete for different tem-

(Continued on Page 102)

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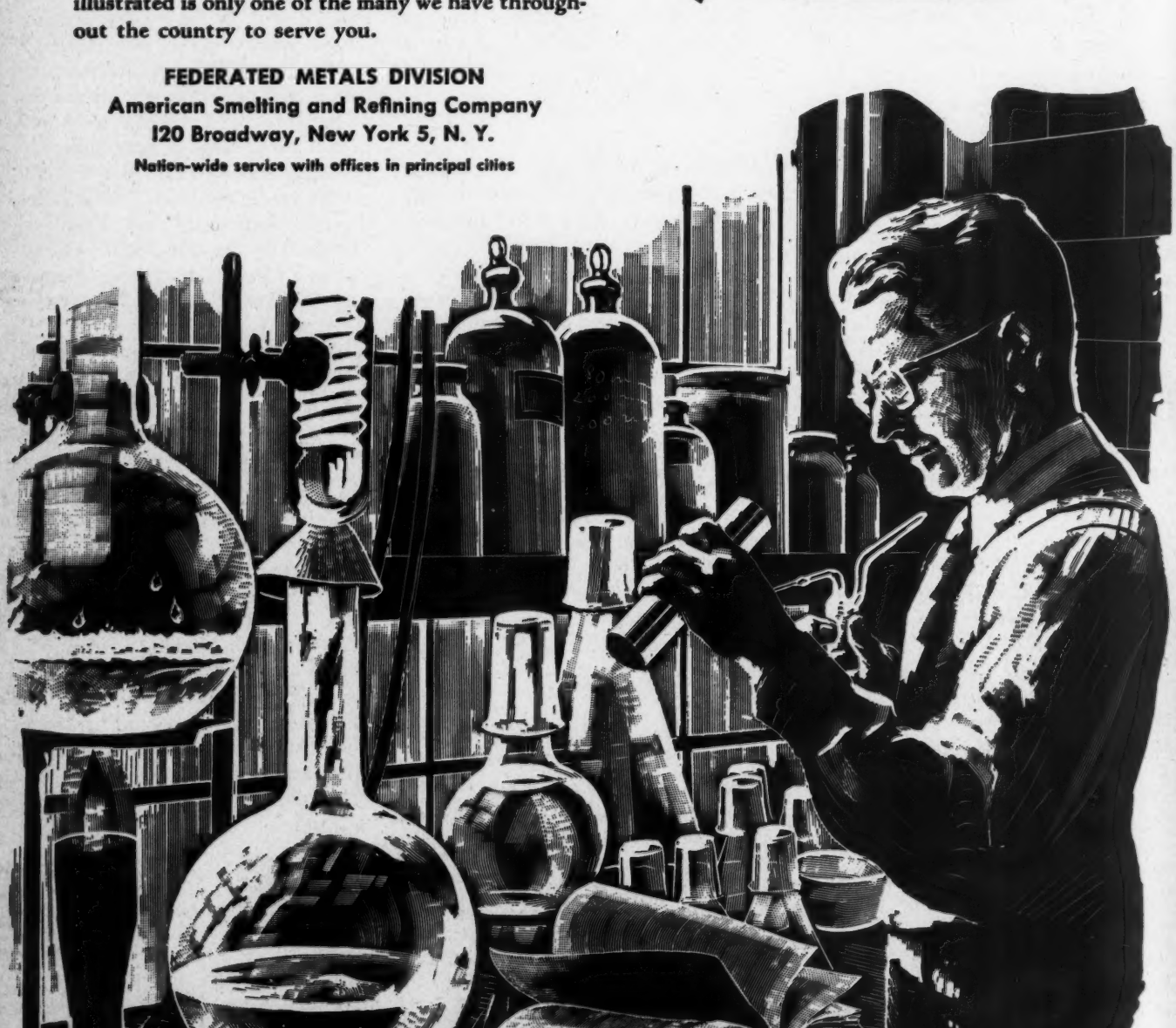

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on both the jolt and squeeze pis
. . . the guide pin is a drive fit in
jolt table, and operates in a cl
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New Literature

(Continued from Page 99)

perature and insulating requirements are given in a 24-page booklet, "Lumnite for Refractory Concrete," incorporating service experience and laboratory investigations since publication of first edition in 1938. Copies may be obtained from Atlas Lumnite Co., 135 East 42nd St., New York 17.

Control valves of many types are illustrated and described in a 12-page booklet of factual data, Bulletin 107, designed for the man who buys or specifies control valves. Distributed on request, by C. B. Hunt & Son, Salem, Ohio.

Accessories and attachments for horizontal boring machines are shown and described in a new 48-page book issued by Giddings & Lewis Machine Tool Co., Fond du Lac, Wis. Unusual arrangement of information provides quick, easy reference as to how, when and where to use each item listed; and actual operations photographs are shown in each case, while pertinent data is carried in an adjoining box. Book will be sent free on request.

Instant reference to information contained, through a pull-card index on cover, is one feature of "Pattern Buyer's Guide," just published by Mastern Pattern Co., 1315 Main Ave., Cleveland 13. Designed to assist in selection of equipment suitable to requirements of job, the 19-page illustrated booklet also contains a glossary of trade terms. Available on request.

Broad usefulness of "Bearcat Lifelong Arbors" in wood and metalworking industries is stressed by Paxson Co., Dowagiac, Mich., which has issued Bulletin 246-1, presenting complete specifications of the units and various applications. Bulletin available on request.

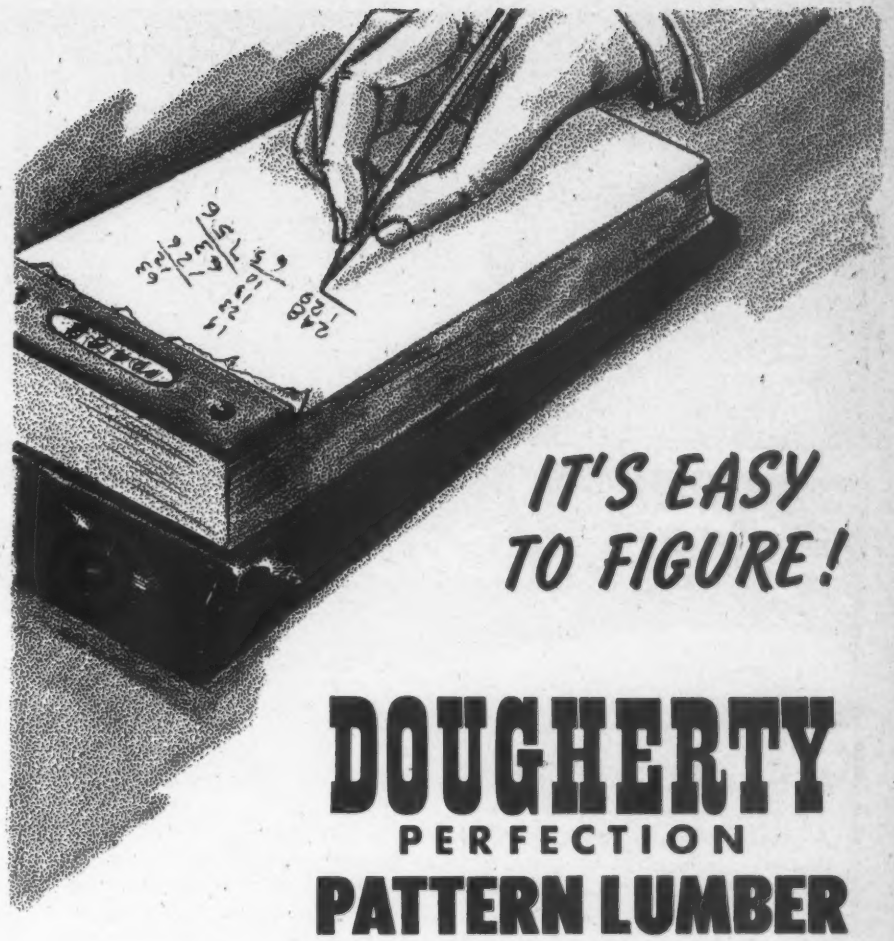
Microfilming in business and industry is subject of "50 Billion Records Can't Be Wrong," handsomely illustrated, 36-page, ring-bound booklet published by

Recordak Corp. (subsidiary of Eastman Kodak Co.), 350 Madison Ave., New York 17. Fundamentals of microfilming—for preserving valuable records, saving storage space and speeding up reference to office records—are explained. All types of equipment, including war developments available to industry for the first time, are shown and discussed. Services — Facsimile Service for paper prints of business records; Microfilming Service for businesses where volume does not require installation of equipment; and Recordak Field Service for consultation on adapting microfilming to specific needs—are reviewed.

American Foundry Equipment Co., 555 South Byrkit Street, Mishawaka, Ind., has issued two new catalogs describing its line of foundry equipment: Catalog 25A contains 12 pages of specifications, dimensions and photographs showing construction and operation of the "Model AM Sandcutter," as well as other models of the unit. Bulletin 10A, in 8 pages, describes all models of the "Core Rod Straightner and Shear Machine," presenting many illustrations as well as specifications and operating data.

Working data and theories regarding basic foundry materials are available in a revised edition of "Foundry Sand Practice," by Clyde A. Sanders and issued by American Colloid Co., 363 W. Superior St., Chicago. Steel, gray iron, malleable and non-ferrous applications are discussed in the 80-page booklet, and a section on casting defects and their causes is included. Sample formulas are given for various types of work. Among subjects considered are: advantages of synthetic over natural sands, selecting the base sand, density—its significance in proper sand selection, moisture, blending molding sand bonds, and compression vs. tensile measurement.

Design and performance of Tennant "Model 15" disc-type floor machine, for such operations as polishing, scrubbing and rug cleaning, are described and shown in Bulletin 81.9, issued by G. H. Tennant Co., 2530 2nd Street North, Minneapolis 11.



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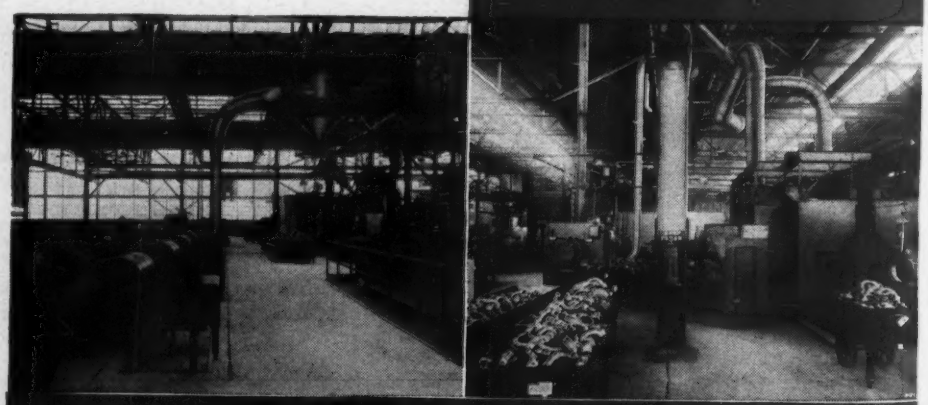
A most rapidly growing trend in the foundry industry is the extension of dust control to cover all dust-creating operations. Foundries which a few short years ago were content to ventilate the cleaning room and shake-out operations, now have complete Schneible Multi-Wash Dust and Fume Control Systems throughout the foundry.

A Schneible system pays dividends in increased human efficiency, aids in attracting and holding better grade labor, and plays a part in lessening rejects and increasing output.

Schneible equipment includes dust collectors, hoods, ductwork and ducting installations required to maintain clean air throughout the foundry — including the continuous removal of dust and fumes from all dust creating zones. These systems give a thorough cleaning of the contaminated air by the Multi-Wash method, separation of the water from the sludge for further use in the collector system, and disposal of the sludge.

Shake-out



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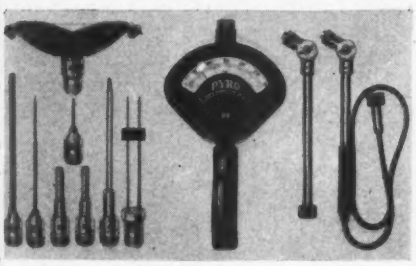
Nunn Manufacturing Co., Evanston, Ill., has developed "Cable-Vise," which forms a loop in wire rope through turning one hex nut with an ordinary wrench. Vise automatically compensates for sizes, and holds loop firmly through clamping or splicing operations. Equipped with swivel base accommodating vice in either vertical or horizontal plane, and permitting rotation through 360° in that plane.

Pyrometer

Pyrometer Instrument Co., 103 Lafayette St., New York 13, has designed an all-purpose instrument, featuring a selection of eight different types of thermocouples, quickly interchangeable without adjustment or recalibration. Selection is offered



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of five different temperature ranges. Unit is completely self-contained, portable and compact, and is constructed in a shock, moisture and dust-proof steel housing. Large 4¾-in. diameter indicator with 4-in. direct reading scale is designed for speed and accuracy, and unit is engineered for wide variety of pyrometer applications.

Shoe Ventilator

Dale Vent-O-Sole, Inc., 60 East 42nd St., New York 17, reveals availability to industry of washable shoe ventilator designed to prevent worsening of blisters and athlete's foot, and permit workmen under treatment to remain on job. Adopted as Government Issue, under designation "Innersoles Plastic, Ventilating Type, Fused," the ventilators are not medicated. Function is entirely mechanical, air being pumped into shoe and circulated by as wearer steps.

Polishing Machine

G. H. Tennant Co., Minneapolis, has introduced an "all-purpose" drum-type floor machine, accommodating 8 and 16-in. accessories, which cleans, waxes and polishes in a single operation. Suitable for all types of floors, unit design allows operation flush to walls, desks and machinery.

Liquid Cleaner

Penetone Co., Tenafly, N. J., has developed a new liquid, water-soluble detergent compound of high

(Continued on Page 106)

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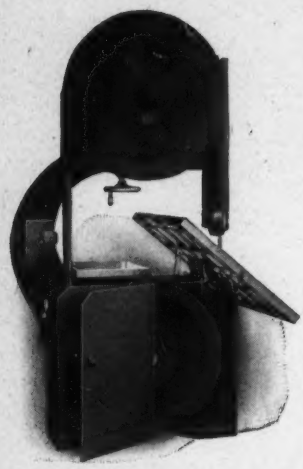

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New Products

(Continued from Page 105)

alkalinity, designed to remove grease, oil and grime accumulations from all surfaces on which steam cleaning is employed. Compound is said to be potent, yet harmless to paint or other finishes. No pre-mixing is required; liquid is instantly soluble in water, and is introduced, in correct proportion, directly into the equipment tank with the water.

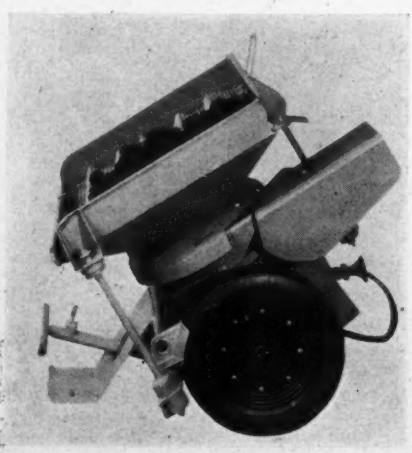
Horizontal Grinders

Master Pneumatic Tool Co. Inc., Cleveland, has announced a new line of "Master Power" horizontal grinders. Features are: Industrial hard chrome used on main wearing parts; light weight through use of magnesium housings; maintained speeds, through positive, quick-acting push valve governors; and sure grip handles, of new design, on wheel end and throttle. Eight models are included in line.

Sand Conditioner

Beardsley & Piper Co., 2540 N. Keeler Ave., Chicago 39, offers a new and improved "Model M Screenarator," that cleans, cuts, screens, double-aerates and blends sand for production foundries and job shops. Basic design is retained, with several mechanical changes incorporated to simplify operation and facilitate longer trouble-free service.

Improved portable Model "M" Screenarator, with pneumatic tires and retractable handle to permit greater mobility, and wheel-locking brace mounted to frame.



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Main frame has been re-designed, and handle has been re-located and made retractable; unit can be moved without passing around to opposite end of machine. Conditioned sand may be discharged 25 feet and elevated from 2 to 10 feet depending on requirements.

Lighting Fixture

Colonial Lighting Co. Inc., 2901 Tonnele Ave., North Bergen, N. J., announces a new "Colonial Woodworth" cold cathode fluorescent lighting fixture, for ceiling mounting or stem suspension. Construction is of 20-gage steel with baked enamel finish, 8 ft. long, 12½ in. wide, and available for two or four lamps. Designed to give 10,000-hr. operating life for lamps. All internal parts interconnected and lead wire brought to outlet for splicing to building service. Transformers are rated at 900 volts, and operated on 110-volt A. C. line.

Melting Furnace

Ajax Engineering Corp., Trenton, N. J., presented a new 20 kw. induction melting furnace for aluminum alloys at the Golden Jubilee Show in Cleveland. Designed as a holding unit in die casting and permanent mold plants, the Ajax-Tama-Wyatt furnace can be placed anywhere on the floor without special foundation. An important feature is elimination of fluxing, the bath being maintained under stirring action which seems to act on the metal in the same manner as nitrogen or chlorine.

Recently-introduced induction heating furnace for aluminum alloys, developed by Ajax Engineering Corp.

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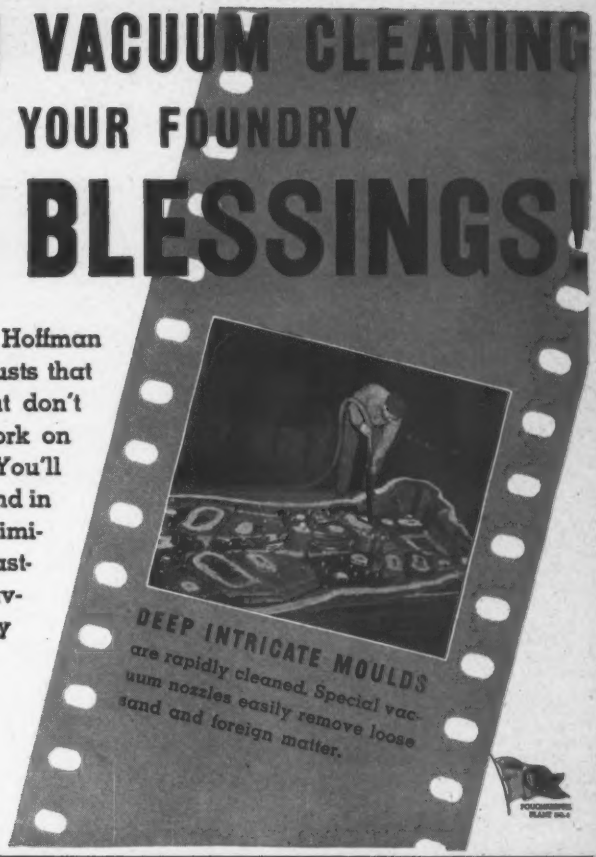

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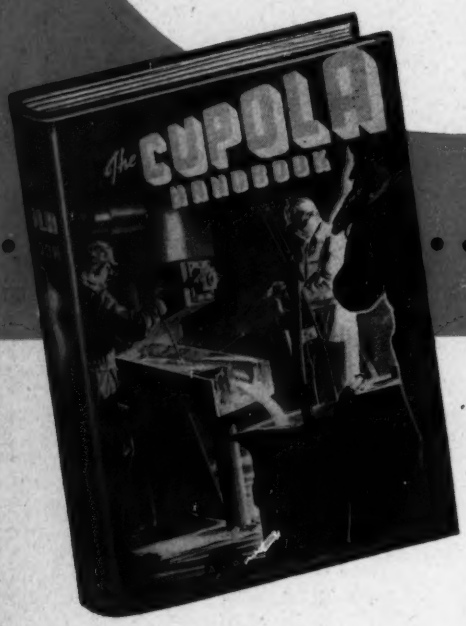

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Chapter Activities

(Continued from Page 96)

tion pictures by courtesy of the same firm.

Shown in the pictures, which included some very interesting scenes from large foundries, were cupola charging, pouring ladles, monorail and crane installations. Chapter Vice-Chairman J. S. Schumacher, Hill & Griffith Co., Cincinnati, acted as presiding officer.

Eastern Canada-Newfoundland

G. D. Turnbull
Shawinigan Foundries, Ltd.
Chairman, Publicity Committee

PROVIDING AN INTERESTING and varied program, Eastern Canada and Newfoundland A.F.A. chapter entertained some 500 members and friends April 26, at Mount Royal Hotel, Montreal. The Smoker and Entertainment replaced the usual Stag Dinner under a revision of plans in view of the situation in hotel accommodations.

Opening the entertainment was a series of boxing bouts sponsored by Griffintown Boys' Club; following which professional performers supplied a program of acts, all heartily enjoyed and many repeatedly encored. Refreshments were served throughout the evening; and the event was adjudged a success warranting a repeat performance next year.

Chapter Chairman G. E. Tait, Dominion Engineering Works, Lachine, Que., was on hand to welcome the gathering, after which he turned the proceedings over to the entertainment committee, which handled arrangements under the chairmanship of Chapter Director J. H. Newman, Chamberlain Engineering, Ltd., Montreal.

Western New York

L. A. Merryman
Tonawanda Iron Corp.
Chapter Secretary

"KNOW YOUR SAND AND produce better castings" was the theme of A. C. Den Breejen, Hydro-Blast Corp., Chicago, discussing "Practical Foundry Sand Problems" at the May 3 meeting of Western New York A.F.A. chapter, in the Hotel Touraine, Buffalo, with 62 foundrymen in attendance and Chapter Chairman A. H. Suckow, Symington-Gould Corp., Depew, N. Y., presiding.

The speaker, member of the Committee on Grading and Fineness, A.F.A. Foundry Sand Research Project, explained in detail the chemical and physical aspects of various sands. Phases of sand control were described, and application of synthetic or natural bonded sand in accordance with equipment available was considered. Emphasis was placed on importance of selecting the type of sand best suited to production of the kind of castings desired.

Mr. Den Breejen illustrated his remarks with colored slides, and exhibited an interesting collection—more than 100 samples—of various sands from all parts of the world. Included was some sand used by the Imperial Japanese Foundry on Honshu.

Lively discussion, which followed the speaker's address, testified to the interest of foundrymen present in the subject.

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